Journal of the Institute of Petroleum

VOL. 44 APRIL 1958 No. 412

CONTENTS

81 **Some Developments in Marine Drilling Foundations**
By A. Kranendonk

97 **Hydrocarbons from Petroleum**
By Frederick D. Rossini

Abstracts 529–780

Book Reviews

Additions to the Library

PRICE 10s 0D A COPY OR
£4-14-6 YEARLY *POST FREE*

Published by the Institute of Petroleum 61 New Cavendish Street London W1

Printed in Great Britain by Richard Clay and Company Ltd Bungay Suffolk

COUNCIL, 1957–58

President

The Rt. Hon. Lord Geddes, C.B.E.

Past-Presidents

Lt.-Col. S. J. M. Auld, O.B.E., M.C., D.Sc.
T. Dewhurst, A.R.C.S.
A. E. Dunstan, D.Sc., F.R.I.C.
E. A. Evans, M.I.Mech.E., F.R.I.C.
F. H. Garner, O.B.E., Ph.D., F.R.I.C.
Sir Stephen Gibson, C.B.E., M.A., M.I.Mech.E.
C. A. P. Southwell, C.B.E., M.C., B.Sc.

Vice-Presidents

E. B. Evans, M.Sc., Ph.D., F.R.I.C.
A. C. Hartley, C.B.E., F.C.G.I., B.Sc.(Eng.), M.I.C.E., M.I.Mech.E.
E. LeQ. Herbert, B.Sc., F.R.I.C., M.I.Chem.E.
H. Hyams
R. B. Southall, C.B.E.
E. J. Sturgess, C.B.E., B.Sc.

Members of Council

W. S. Ault, B.A.
V. Biske, B.Sc., LL.M., F.R.I.C.
G. A. Dickins, B.Sc., A.R.I.C.
E. J. Dunstan, M.Sc., M.I.Chem.E.
F. L. Garton, M.A., B.Sc.
A. J. Goodfellow, B.Sc., A.R.I.C.
M. E. Hubbard, B.A., M.I.Mech.E.
E. C. Masterson, B.Sc.
T. W. Mathias, O.B.E., M.A.
F. Morton, Ph.D., D.Sc., F.R.I.C.
J. S. Parker, M.A., B.Sc.
K. E. W. Ridler, Ph.D.
A. J. Ruthven-Murray, C.M.G., M.A., B.Sc.
D. L. Samuel, B.Sc., A.R.I.C.
G. H. Smith, Ph.D.
A. R. Stark, B.Sc., A.R.I.C.
W. H. Thomas, A.R.S.M., F.R.I.C.
G. H. Thornley, M.Sc.
A. T. Wilford, B.Sc., F.R.I.C.
C. G. Williams, D.Sc., M.I.Mech.E., F.R.Ae.S.
C. S. Windebank, B.Sc., M.S.

Ex-Officio

S. A. Berridge, B.Sc.
A. S. Brooman, B.Sc.
A. H. Chatting
J. C. Jewell, B.Sc., A.R.C.S., A.R.I.C.
L. S. Thornes, B.Sc., Ph.D., D.I.C., M.R.C.S.
J. C. Wood-Mallock

Honorary Secretary

C. Chilvers, B.Sc., F.R.I.C.

Honorary Treasurer

G. H. Coxon

General Secretary

D. A. Hough, T.D., F.I.A.C.

Honorary Editor

E. B. Evans, M.Sc., Ph.D., F.R.I.C.

Honorary Associate Editor

D. L. Samuel, B.Sc., A.R.I.C.

Editor

George Sell

Honorary Secretaries of Branches

Bahrain Branch: D. G. Johnstone, c/o Bahrain Petroleum Co. Ltd., Awali, Bahrain, Persian Gulf.

Essex Branch: E. G. Hannah, London and Thames Haven Oil Wharves Ltd., Thames Haven, Essex.

Fawley Branch: S. A. Berridge, B.Sc., c/o Esso Petroleum Co. Ltd., Fawley, Southampton.

Kuwait Branch: R. J. L. Stephens, c/o Kuwait Oil Co. Ltd., Ahmadi, Kuwait.

London Branch: S. C. Price, F.C.S., c/o Monsanto Chemicals Ltd., Monsanto House, 10–18 Victoria Street, London, S.W.1.

Northern Branch: H. Kaye, B.Sc., A.M.I.Chem.E., c/o Manchester Oil Refinery Ltd., Twining Road, Trafford Park, Manchester 17.

Scottish Branch: W. M. Stirling, A.H-W.C., A.M.I.E.E., Scottish Oils Ltd., Middleton Hall, Uphall, Broxburn, W. Lothian.

South-Eastern Branch: J. R. Moore, Fisher Governor Co. Ltd., Airport Works, Rochester, Kent.

South Wales Branch: D. J. Lewis, BP Refinery (Llandarcy) Ltd., Llandarcy, Glam.

Stanlow Branch: A. S. Brooman, B.Sc., 11 Grange Crescent, Hooton, Wirral, Cheshire.

Trinidad Branch: S. Howe, c/o Texaco Trinidad Inc., Forest Reserve, Trinidad, B.W.I.

THE INSTITUTE OF PETROLEUM

AN Ordinary General Meeting of the Institute of Petroleum was held at 26 Portland Place, London, W.1, on 4 September 1957, the Chair being taken by E. J. Sturgess, C.B.E., a vice-president of the Institute.

The General Secretary read the minutes of the previous meeting, which were confirmed and signed as a correct record. He also announced the names of members elected since the previous meeting.

The Chairman, introducing the author of the paper, said: It is not often that the IP has a paper presented on drilling, and the particular problems of marine drilling are a fascinating subject.

Mr Kranendonk was educated at Delft University, where he took a degree in Civil Engineering, and joined the Bataafsche Petroleum Maatschappij in 1935. In 1947 he was put in charge of the development work for marine drilling platforms. He is now head of the Civil Engineering Department of the B.P.M., a main section of which deals with this work at the present time.

SOME DEVELOPMENTS IN MARINE DRILLING FOUNDATIONS *

By A. KRANENDONK †

SUMMARY

The requirements of a drilling platform are discussed in general terms and the considerations arising in the choice between three basic types, which are briefly described, are dealt with. The evolution and construction of the three different platforms, designed to meet widely varying conditions, are dealt with specifically.

IN May 1946 the first offshore well in the Gulf of Mexico was started off the coast of Louisiana. The search for oil in those parts of the earth which are covered with water has developed to an enormous extent. Although it is not correct to say that no drilling in water took place before that time, it was only after production of oil on a large scale began from the sea bottom off the coasts of Texas and Louisiana that " marine drilling " or, as it is generally called in the U.S.A., " offshore drilling," came into the limelight.

It is almost impossible to open an American oil periodical without coming across one or more advertisements, statements, or articles regarding offshore drilling. Seldom has a new development in engineering appealed so much to the imagination of man, especially in the U.S.A., as that relating to the problems connected with the search for oil under water.

Although many difficulties may be experienced in the exploration and exploitation of a marine concession, and although there are many interesting problems which require special solutions, the most spectacular aspect of the subject is undoubtedly what is sometimes called the " artificial island."

It is beyond the scope of this paper to deal with all the problems connected with drilling in water, such as the method used in geological exploration of the region, and the very important question of transport, *i.e.* the conveyance to and from the drilling site of men and materials, and the removal of oil, if found, but in this paper some particulars will be given of structures from which wells have been drilled and which have been designed by the Royal Dutch/Shell Group for parts of the world outside the U.S.A.

The main feature of the design is to provide the driller with the space above water to enable him to drill an oil well as economically as possible, or in other words to make a foundation above water for the drilling equipment, which in general consists of:

(1) drilling rig with rotary table and draw-works;
(2) source of power (diesel engines);
(3) drill pipes and casing (horizontal and vertical);
(4) mud tanks with mud ditches for supply and drainage, screens, etc., mud pumps, mixing plant for mud, water and oil tanks;
(5) cementing outfit;
(6) Schlumberger apparatus;
(7) storage accommodation for chemicals, dry material for mud flush, cement.

In drilling on land few difficulties will be experienced, as a rule, in finding room for the above. Even when the drilling site is too far from civilization to permit of daily journeys there and back, it will still be easy to find room on the site for temporary living accommodation.

If, however, this equipment is to be used in a place surrounded by water, special structures have to be built to support it all. It will be clear that often large and heavy foundations will be required, which will not only have to be able to support the heavy weight of the drilling equipment, but will also have to be capable of withstanding the enormous forces

* MS originally received 25 July 1956; revised MS received 5 July 1957. † N. V. De Bataafsche Petroleum Maatschappij.

COUNCIL, 1957–58

President

The Rt. Hon. Lord Geddes, C.B.E.

Past-Presidents

Lt.-Col. S. J. M. Auld, O.B.E., M.C., D.Sc.
T. Dewhurst, A.R.C.S.
A. E. Dunstan, D.Sc., F.R.I.C.
E. A. Evans, M.I.Mech.E., F.R.I.C.
F. H. Garner, O.B.E., Ph.D., F.R.I.C.
Sir Stephen Gibson, C.B.E., M.A., M.I.Mech.E.
C. A. P. Southwell, C.B.E., M.C., B.Sc.

Vice-Presidents

E. B. Evans, M.Sc., Ph.D., F.R.I.C.
A. C. Hartley, C.B.E., F.C.G.I., B.Sc.(Eng.), M.I.C.E., M.I.Mech.E.
E. LeQ. Herbert, B.Sc., F.R.I.C., M.I.Chem.E.
H. Hyams
R. B. Southall, C.B.E.
E. J. Sturgess, C.B.E., B.Sc.

Members of Council

W. S. Ault, B.A.
V. Biske, B.Sc., LL.M., F.R.I.C.
G. A. Dickins, B.Sc., A.R.I.C.
E. J. Dunstan, M.Sc., M.I.Chem.E.
F. L. Garton, M.A., B.Sc.
A. J. Goodfellow, B.Sc., A.R.I.C.
M. E. Hubbard, B.A., M.I.Mech.E.
E. C. Masterson, B.Sc.
T. W. Mathias, O.B.E., M.A.
F. Morton, Ph.D., D.Sc., F.R.I.C.
J. S. Parker, M.A., B.Sc.
K. E. W. Ridler, Ph.D.
A. J. Ruthven-Murray, C.M.G., M.A., B.Sc.
D. L. Samuel, B.Sc., A.R.I.C.
G. H. Smith, Ph.D.
A. R. Stark, B.Sc., A.R.I.C.
W. H. Thomas, A.R.S.M., F.R.I.C.
G. H. Thornley, M.Sc.
A. T. Wilford, B.Sc., F.R.I.C.
C. G. Williams, D.Sc., M.I.Mech.E., F.R.Ae.S.
C. S. Windebank, B.Sc., M.S.

Ex-Officio

S. A. Berridge, B.Sc.
A. S. Brooman, B.Sc.
A. H. Chatting
J. C. Jewell, B.Sc., A.R.C.S., A.R.I.C.
L. S. Thornes, B.Sc., Ph.D., D.I.C., M.R.C.S.
J. C. Wood-Mallock

Honorary Secretary

C. Chilvers, B.Sc., F.R.I.C.

Honorary Treasurer

G. H. Coxon

General Secretary

D. A. Hough, T.D., F.I.A.C.

Honorary Editor

E. B. Evans, M.Sc., Ph.D., F.R.I.C.

Honorary Associate Editor

D. L. Samuel, B.Sc., A.R.I.C.

Editor

George Sell

Honorary Secretaries of Branches

Bahrain Branch: D. G. Johnstone, c/o Bahrain Petroleum Co. Ltd., Awali, Bahrain, Persian Gulf.

Essex Branch: E. G. Hannah, London and Thames Haven Oil Wharves Ltd., Thames Haven, Essex.

Fawley Branch: S. A. Berridge, B.Sc., c/o Esso Petroleum Co. Ltd., Fawley, Southampton.

Kuwait Branch: R. J. L. Stephens, c/o Kuwait Oil Co. Ltd., Ahmadi, Kuwait.

London Branch: S. C. Price, F.C.S., c/o Monsanto Chemicals Ltd., Monsanto House, 10–18 Victoria Street, London, S.W.1.

Northern Branch: H. Kaye, B.Sc., A.M.I.Chem.E., c/o Manchester Oil Refinery Ltd., Twining Road, Trafford Park, Manchester 17.

Scottish Branch: W. M. Stirling, A.H-W.C., A.M.I.E.E., Scottish Oils Ltd., Middleton Hall, Uphall, Broxburn, W. Lothian.

South-Eastern Branch: J. R. Moore, Fisher Governor Co. Ltd., Airport Works, Rochester, Kent.

South Wales Branch: D. J. Lewis, BP Refinery (Llandarcy) Ltd., Llandarcy, Glam.

Stanlow Branch: A. S. Brooman, B.Sc., 11 Grange Crescent, Hooton, Wirral, Cheshire.

Trinidad Branch: S. Howe, c/o Texaco Trinidad Inc., Forest Reserve, Trinidad, B.W.I.

THE INSTITUTE OF PETROLEUM

AN Ordinary General Meeting of the Institute of Petroleum was held at 26 Portland Place, London, W.1, on 4 September 1957, the Chair being taken by E. J. Sturgess, C.B.E., a vice-president of the Institute.

The General Secretary read the minutes of the previous meeting, which were confirmed and signed as a correct record. He also announced the names of members elected since the previous meeting.

The Chairman, introducing the author of the paper, said: It is not often that the IP has a paper presented on drilling, and the particular problems of marine drilling are a fascinating subject.

Mr Kranendonk was educated at Delft University, where he took a degree in Civil Engineering, and joined the Bataafsche Petroleum Maatschappij in 1935. In 1947 he was put in charge of the development work for marine drilling platforms. He is now head of the Civil Engineering Department of the B.P.M., a main section of which deals with this work at the present time.

SOME DEVELOPMENTS IN MARINE DRILLING FOUNDATIONS *

By A. KRANENDONK †

SUMMARY

The requirements of a drilling platform are discussed in general terms and the considerations arising in the choice between three basic types, which are briefly described, are dealt with. The evolution and construction of the three different platforms, designed to meet widely varying conditions, are dealt with specifically.

IN May 1946 the first offshore well in the Gulf of Mexico was started off the coast of Louisiana. The search for oil in those parts of the earth which are covered with water has developed to an enormous extent. Although it is not correct to say that no drilling in water took place before that time, it was only after production of oil on a large scale began from the sea bottom off the coasts of Texas and Louisiana that " marine drilling " or, as it is generally called in the U.S.A., " offshore drilling," came into the limelight.

It is almost impossible to open an American oil periodical without coming across one or more advertisements, statements, or articles regarding offshore drilling. Seldom has a new development in engineering appealed so much to the imagination of man, especially in the U.S.A., as that relating to the problems connected with the search for oil under water.

Although many difficulties may be experienced in the exploration and exploitation of a marine concession, and although there are many interesting problems which require special solutions, the most spectacular aspect of the subject is undoubtedly what is sometimes called the " artificial island."

It is beyond the scope of this paper to deal with all the problems connected with drilling in water, such as the method used in geological exploration of the region, and the very important question of transport, *i.e.* the conveyance to and from the drilling site of men and materials, and the removal of oil, if found, but in this paper some particulars will be given of structures from which wells have been drilled and which have been designed by the Royal Dutch/Shell Group for parts of the world outside the U.S.A.

The main feature of the design is to provide the driller with the space above water to enable him to drill an oil well as economically as possible, or in other words to make a foundation above water for the drilling equipment, which in general consists of:

(1) drilling rig with rotary table and draw-works;
(2) source of power (diesel engines);
(3) drill pipes and casing (horizontal and vertical);
(4) mud tanks with mud ditches for supply and drainage, screens, etc., mud pumps, mixing plant for mud, water and oil tanks;
(5) cementing outfit;
(6) Schlumberger apparatus;
(7) storage accommodation for chemicals, dry material for mud flush, cement.

In drilling on land few difficulties will be experienced, as a rule, in finding room for the above. Even when the drilling site is too far from civilization to permit of daily journeys there and back, it will still be easy to find room on the site for temporary living accommodation.

If, however, this equipment is to be used in a place surrounded by water, special structures have to be built to support it all. It will be clear that often large and heavy foundations will be required, which will not only have to be able to support the heavy weight of the drilling equipment, but will also have to be capable of withstanding the enormous forces

* MS originally received 25 July 1956; revised MS received 5 July 1957. † N. V. De Bataafsche Petroleum Maatschappij.

H

due to drilling, as well as those which are the results of the action of waves and wind.

The cost of these structures is exceptionally high, and thorough studies are necessary to keep the cost as low as possible.

It is, however, not possible to make one general design for a foundation; the most economical solution of the problem will have to be ascertained for each concession individually. For this purpose, it is in the first place of importance to know whether it is a question of drilling a single exploration well, or whether it is the intention to proceed to exploitation of an already proven reservoir. The depth to which it is desired to drill will also have to be known, but at the same time a study should be made of the local conditions, of which the following may be mentioned:

(1) water conditions: depth, tides, directions and speeds of currents, waves to be expected (height and lengths);

(2) meteorological conditions: observations as regards the wind, occurrence of hurricanes, tornadoes, or whatever they may be called;

(3) bearing conditions of the soil under the sea or lake;

(4) geographical conditions: presence of harbours, facilities for assembling equipment, distance from location, etc.;

(5) the presence and availability of auxiliary services and equipment: tugs, barges, floating cranes, etc.

All these circumstances together determine the final design of the structure. Although a great variety of systems can be applied, these can in general be reduced to three principal ones:

(1) *A Small Platform to be Used in Conjunction with a Drilling Barge* (Fig 1)

At all events the drilling rig with rotary table, and drawworks with driving mechanism, must have a solid foundation, and it seems attractive to restrict the area of the foundation to this minimum. For drilling a hole not deeper than about 8000 ft this layout requires an area of about 50 ft × 25 ft (Fig 2). All other equipment should then be accommodated on a barge which can be moved very easily from one foundation to the other (Fig 1).

This solution has great advantages:

(*a*) if no oil is found, the cost of the foundation has been kept to a minimum;

(*b*) if, on the other hand, oil is found, a floor is left which provides just enough space for the Christmas tree;

(*c*) the cost of transporting the drilling equipment from one drilling site to another is kept very low.

It is, however, obvious that the possibility of working with this combination depends to a large extent on local conditions. If the concession is situated in a region where long spells of bad weather with much wind and, consequently, high waves, may be expected,

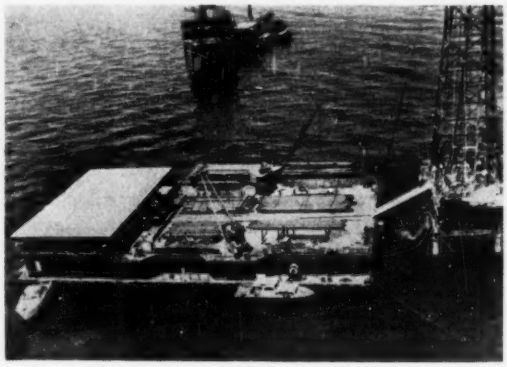


FIG 1

RIG FOUNDATION WITH DRILLING BARGE
(Lake Maracaibo)

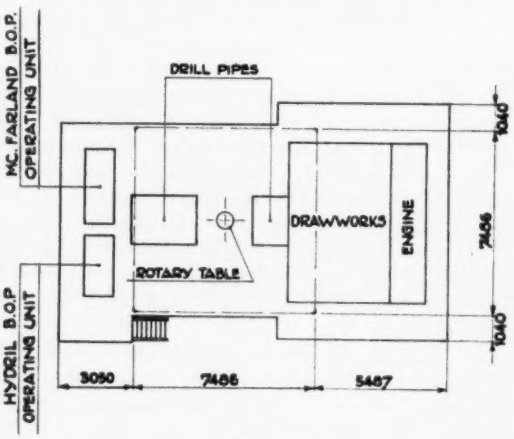


FIG 2

LAYOUT OF SMALL DRILLING PLATFORM

drilling operations may have to be interrupted so often and perhaps for so long a time that the drawbacks would be far greater than the advantages originally expected.

(2) *A Large Self-contained Platform*

If the use of a drilling barge cannot be recommended, all the material required has to be accommodated on the drilling platform. There are many ways of doing this: one large floor may be designed, or preference may be given to the construction of two smaller ones, one on top of the other. If the location is not too far from the coast, it may be decided, for instance, to lay water, oil, and mud lines from the coast to the platform, in order to keep the platform's area and load on it as small as possible. From these large drilling foundations more than one well will be

drilled in most cases (sometimes four to eight), in order to reduce the cost per well as much as possible (Fig 3).

Construction of these islands on piles, which is the most obvious method, has the disadvantage that, should no oil be found, a large and expensive structure becomes useless. In this case the floors can be taken away, but anything which is under water can be only removed at a comparatively high cost.

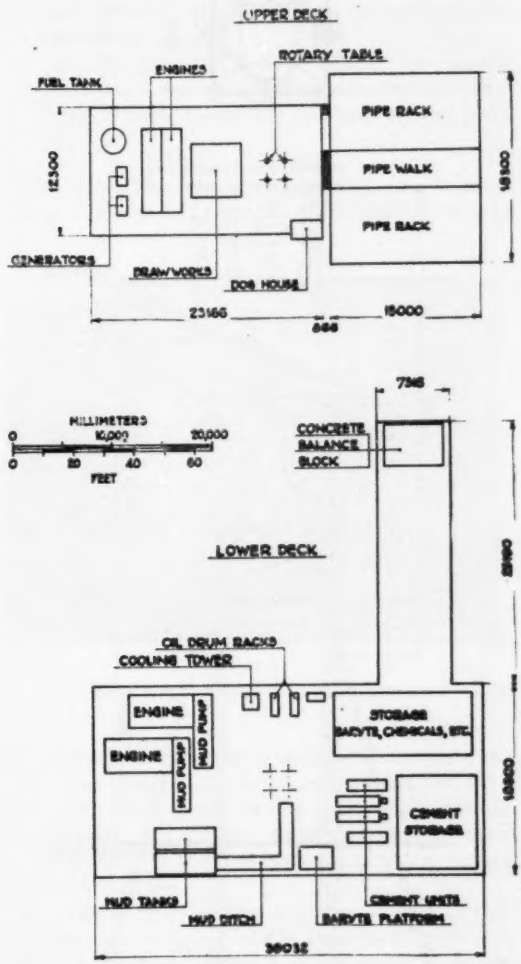


FIG 3

LAYOUT OF SELF-CONTAINED PLATFORM

(3) *A Self-contained Mobile Unit*

The solution has therefore been sought in the design of "mobile units," *i.e.* islands which can be moved fairly easily as a whole. Here all the equipment remains on the structure, which is removed in its entirety to the next location.

Many of these very expensive units are already in use in the U.S.A.; furthermore, many ideas concerning them have been published but not yet put into effect. Mobile units can be classified under three types:

(*a*) *fixed-deck units* consisting of a fixed deck on a submersible barge; this barge is sunk and rests on the bottom, leaving the upper drilling deck at a fixed height above the bottom hull (Fig 4);

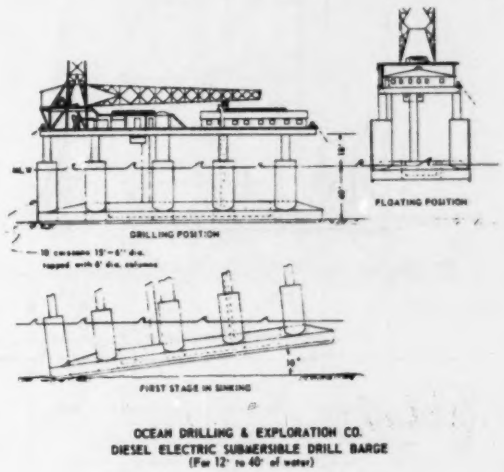


FIG 4

SELF-CONTAINED MOBILE UNIT
(ODECO unit)

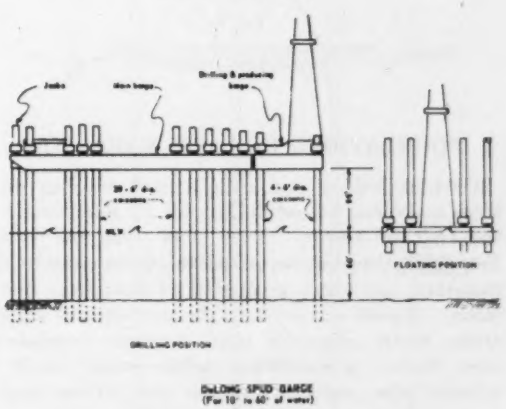


FIG 5

SELF-CONTAINED MOBILE UNIT
(DeLong type)

(*b*) *vertical-lift units* have a floating hull on which the drilling equipment is installed and which is mechanically lifted out of the water after the columns which support the structure have been driven into the bottom (Fig 5);

(*c*) *elevated-deck units* which have an elevated drilling deck at a fixed height above the still

water level and legs or a lower hull with extensible columns on which the elevated deck rests (Fig 6).

Nearly all these types of structure have been designed for use in the Gulf of Mexico, and details can be found in various American papers.

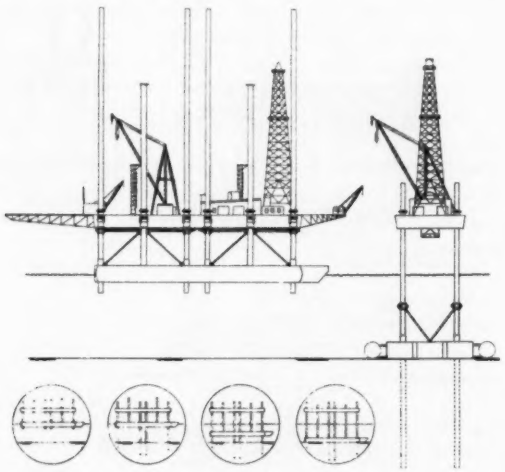


FIG 6
SELF-CONTAINED MOBILE UNIT
(Bethlehem unit)

FOUNDATIONS IN LAKE MARACAIBO

Offshore drilling was being carried out here on a large scale long before drilling for oil commenced in the Gulf of Mexico. Ever since 1925 the Creole Petroleum Corporation, an affiliated company of the Standard, have been producing oil from Lake Maracaibo. A start was made in the very shallow coastal areas, where originally solid concrete foundations were built; in somewhat deeper water 10–15 ft wooden piles were driven into the bottom and a wooden floor was laid on top of them. Owing to the fact that these wooden structures suffered greatly from attack by teredos, wooden piles were discarded in favour of concrete piles. Originally the normal methods used on land were applied, and the platforms became so large that all the drilling material could be accommodated on them. However, it soon became evident that, where the depth of the water permitted, it would be far more advantageous to build a small drilling platform and use what is called a "drilling barge" or "drilling tender."

This type of foundation was able to develop very gradually, for it took years before deeper waters were reached. By that time, however, a construction had been developed which consisted of four hollow concrete piles about 4 ft in diameter. These piles were joined at the top by means of steel girders; they were used at depths of down to about 65 ft.

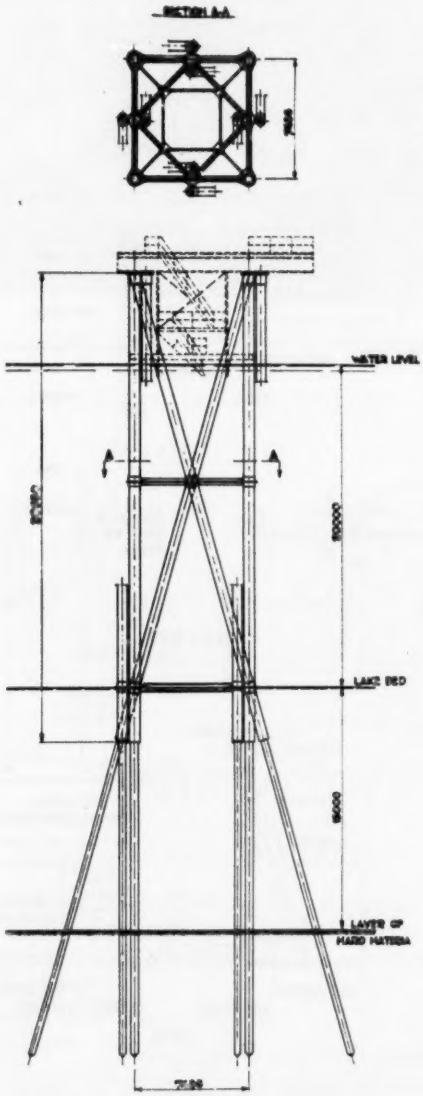


FIG 7
JACKET TYPE FOUNDATION

However, 90 per cent of the area of the concessions granted to the Royal Dutch/Shell in Lake Maracaibo after the second world war lies in waters with a depth varying from 65 to 110 ft.

The task of designing a foundation for exploration purposes in this area was originally tackled by develop-

ing a supporting structure consisting of twelve piles, four vertical and eight diagonal. In order to enable these piles to be driven in the right place so that the prefabricated floor could be placed on them without difficulty, a template was made through which the piles were driven. This template, besides ensuring correct placing of the piles, offered the following advantages:

(1) the possibility of applying bracings to reduce buckling lengths without the necessity for underwater work;

(2) the possibility of protecting the bearing pile from corrosion by filling the annular space between outer casing and pile with cement grout (Fig 7).

However, when these foundations had to be made in large numbers and placed at the rate of one or even

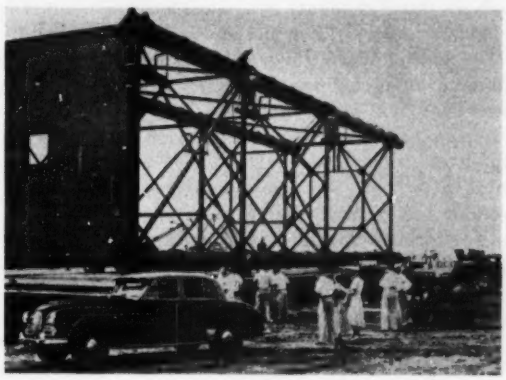


FIG 8
SIMPLIFIED JACKET TYPE FOUNDATION

two per week, the costs were considered too high, and in the first instance an endeavour was made to dispense with driving the twelve piles, especially the diagonal ones. In addition, a construction was looked for which could be adapted more easily to the varying depth of the water.

By revising the loading schemes, a very simple structure was designed which consists of only four vertical piles, each having a diameter of 24 inches, as against the 16 inches of the original twelve-pile design. By standardizing the parts in lengths of 24, 30, and 36 ft, templates can be made which are suitable for the various depths of water (Fig 8).

The blowout preventer and, later, the Christmas tree, can remain on the lower floor. The upper floor can, if necessary, be moved as a whole, together with rig, rotary table, and drawworks. The standardized parts can also be used to form foundations from which two wells can be drilled (Fig 9).

These constructions, with different floors, can also be used for block stations (Fig 10).

Although from an engineering and operational point of view these structures have given satisfactory

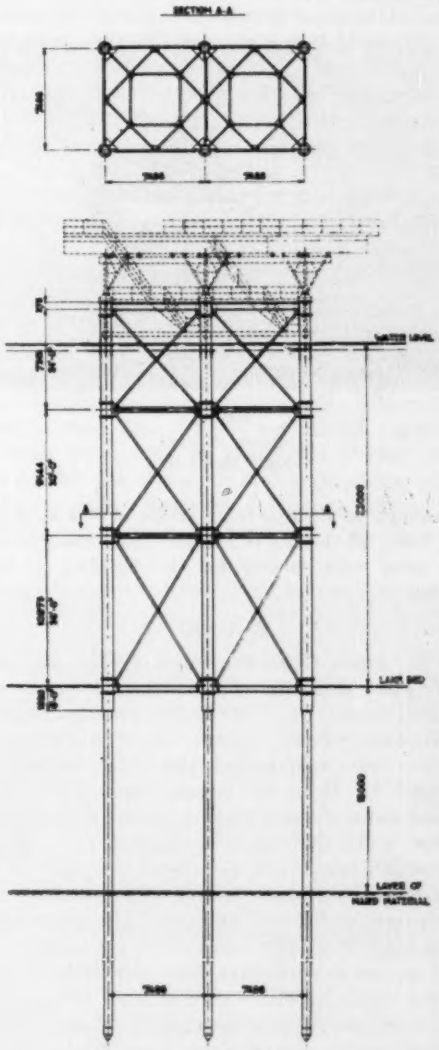


FIG 9
FOUNDATION FOR TWO WELLS

results, the use of steel causes serious problems, particularly in the extremely aggressive water of Lake Maracaibo.

Corrosion attack is so virulent that unprotected steel structures cannot be considered to retain their full strength longer than a few years, and it is expected that high maintenance costs will occur in future.

Although protective coating, such as a hot-dipped galvanizing or a metal-sprayed surface combined with

various kinds of paints have been applied, it is felt that this would not extend the lifetime sufficiently, and a new type of structure is therefore being developed consisting of four 54-inch hollow post-stressed concrete piles.

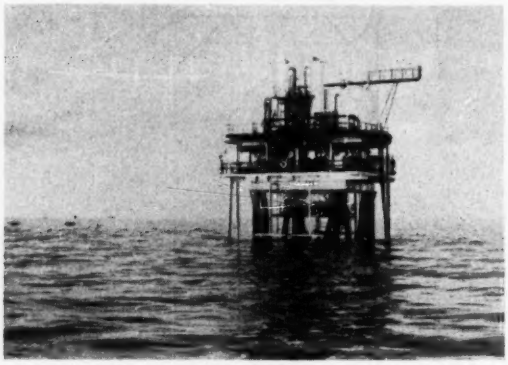


FIG 10
BLOCK STATION
(Lake Maracaibo)

Although no drilling foundations of this kind have been built, 36-ft piles of similar make have recently been used with success for the building of block stations.

BRUNEI

In the South China Sea much drilling activity is taking place along the coast of the state of Brunei, in NW. Borneo. In 1952 the first drilling island was placed there, followed by two others in 1954, whilst a further three islands were placed in position early in 1956. Of these six islands three will then be situated about one mile from the shore, and one about 2 miles, whilst two others are located at far greater distances offshore (12 to 25 miles).

The production of the Seria oilfield is obtained from a comparatively narrow strip along the coast, but as far back as 1936, when some wells were drilled just in the sea, endeavours were made to extend this strip into the water. This was done from wooden platforms on wooden or concrete piles, connected with the shore by means of a road on piles which was also suitable for vehicles. During the second world war and for the first few years after it, development further seaward was at a standstill, and not until 1950 did preparatory work start on the building of an island about one mile offshore, from which it would be possible to drill four wells.

Work with a drilling tender was impossible, because weather conditions throughout the greater part of the year would not permit this; the coast is entirely open and there is a considerable swell almost the whole year round. After a study of the meteorological and oceanographical data it was obvious: (1) that only a completely self-contained island offered possibilities of uninterrupted drilling; (2) that from April to the end of July it would be impossible to take people by boat through the surf to the island, while even in the other months this could be done only on, at most, 40 per cent of the number of days, and that difficulties would very often also be experienced in the transport of materials by boat.

In order to avoid these difficulties it was decided to construct a cableway for the transport of material such as pipes, cement, etc., and for conveying the personnel to the drilling site and back every day.

The area of the drilling platform was reduced to a minimum by laying lines for mud, oil, and water from the shore.

In this case, too, use was made of steel piles for supporting the drilling platform. It was intended to drive these piles through a template, so that they would be placed exactly in position; this would enable the platform to be fully prefabricated, and work at sea could thus be reduced to a minimum.

The original plan was to make small units consisting of four vertical piles standing in a square, the sides of which were 15 ft long, connected by means of bracings. It was considered that these units could be transported comparatively easily and placed in position quickly. The difficulty of locating them at exactly the right distance apart made it desirable to study the possibility of making one large template which could be placed in position in one piece.

The water was not so deep as in Lake Maracaibo—about 30 ft—but such a structure would still weigh about 95–100 tons, even if the area of the platform were restricted to a minimum. In the design the height had already been restricted as far as possible by planning the part above water as a separate steel structure which could, if necessary, be taken down easily (Figs 11–13).

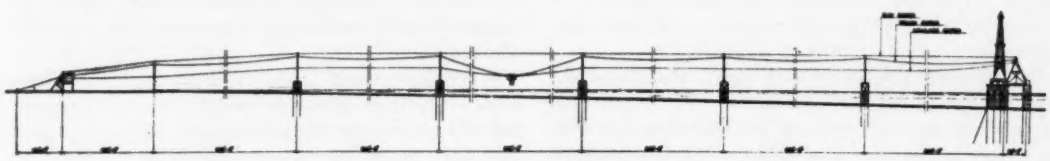


FIG 11
GENERAL ARRANGEMENT OF AERIAL ROPEWAY WITH SHORE AND END STATIONS

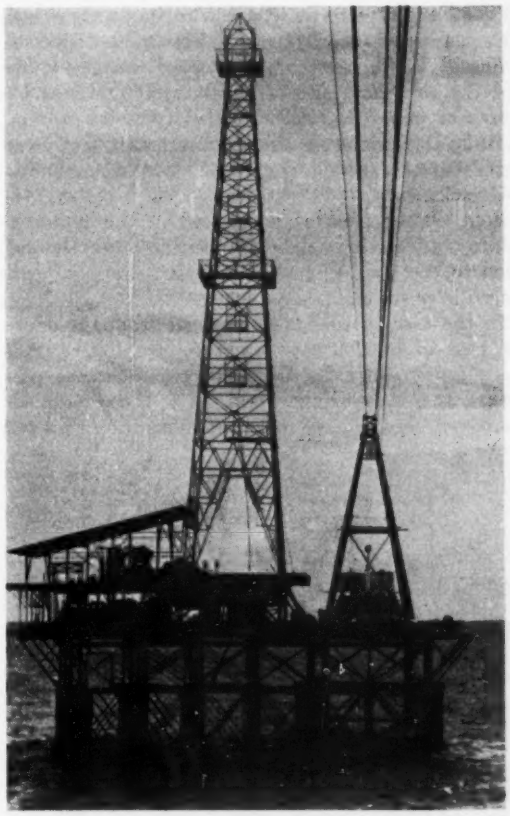


FIG 12
SELF-CONTAINED PLATFORM
(Seria)

The structure comprised, in all, twenty-eight vertical piles and four diagonal ones, the latter having to take the horizontal force due to the cableway. All piles were 16 inches in diameter; the maximum pile load was about 70 tons. The comparatively large number of vertical piles (twenty-eight) was chosen, on the one hand, as the result of the originally adopted pattern of 15 × 15 ft and, on the other hand, because, owing to the short time available for preparation, sufficient data could not be obtained regarding the subsoil. Borings on land had shown that a layer of sand about 35 ft thick was present, and that under that was a layer of mud, peat, and sandy clay, the thickness of which was unknown but was at least 60 ft; and there were indications that the first-mentioned layer increased somewhat in thickness in a seaward direction. It was hoped that a layer of sand at least 50 ft thick about one mile offshore would be found in which the platform could be based. A few weeks before the structure was scheduled to be placed in position some investigations of the sea bottom were carried out. It was then found that the layer of sand became constantly thinner, and that on the spot where the platform was to be located it was only 5 ft thick, after which resistance was experienced only at a depth of 50–65 ft below the sea bed. When some test piles had been driven it was decided to increase the length of the piles to about 120 ft, so that they would penetrate some 70 ft into the sea bed. It was, however, obvious that the piles of the foundation were chiefly based on friction, but thanks to the large number of piles used, no sagging took place during drilling operations.

Once this platform was ready it was easier to carry out soil borings, and these supplied sufficient information to give the assurance that with piles about 140 ft in length sufficient point resistance would be obtained. Consequently, it was decided to reduce the number of piles in the case of subsequent foundations, owing to which the floor would become heavier, but which reduction (from twenty-eight to twelve piles) nevertheless offered considerable advantages, bearing in mind that, if no oil were found, the structure under water must be considered as lost. Furthermore, for the following constructions an island with two complete floors was designed, so as to provide more space for the drilling crew. The result is

FIG 13
AERIAL ROPEWAY TO PLATFORM
(Seria)

represented in the ground plan as shown in Fig 3, whilst the substructure was simplified considerably (Fig 14).

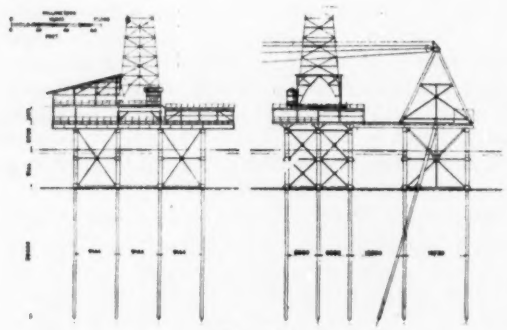


FIG 14

SIMPLIFIED STRUCTURE FOR SELF-CONTAINED PLATFORM

Owing to the smaller weight, it was possible to make the template higher in this case, thus enabling the intermediate structure to be dispensed with.

The portal of the cableway has an entirely separate foundation; this facilitates placing it, since it is no longer necessary that the distance between the main foundation of the island and that of the cableway portal should be adhered to to the inch.

As stated above, four wells were drilled from these platforms. According to the first design the 24-ft derrick had to be slid along the drilling deck; later a 30-ft derrick was designed with a large water table so that the crown block could be moved so as to hang vertically over the boreholes, which lie in a 6-ft square (Fig 15).

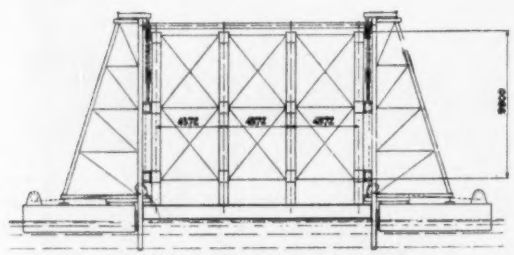


FIG 15

TRANSPORT OF JACKET FOR PLATFORM

In building these islands the most important part to be considered is the placing of the template. Once this has been located in the right position, the driving of the piles is a matter of routine.

For assembling these structures use was made of a temporary platform mounted between two barges, each with a capacity of 200 tons. On these barges lifting towers were fitted, to which the tubes of the template could be fastened. In this way a very rigid unit was obtained for transport (Figs 15 and 16).

At the destination the connexions were removed and the template lowered in about 10 minutes by means of pulley blocks suspended from the towers. In order to prevent the barges from listing they were connected at the ends by girders consisting of Bailey bridge elements.

Four corner piles were inserted in the template before transporting, and by means of these it was fixed to the sea bed immediately after it had been placed in position.

In the case of islands located far from the shore the cost of a cableway would be prohibitive, and therefore special living accommodation for the personnel and a helicopter deck have been designed. Moreover, considerably more space has been reserved for mud and drill pipes, so as to make the island less dependent on regular supply from outside.

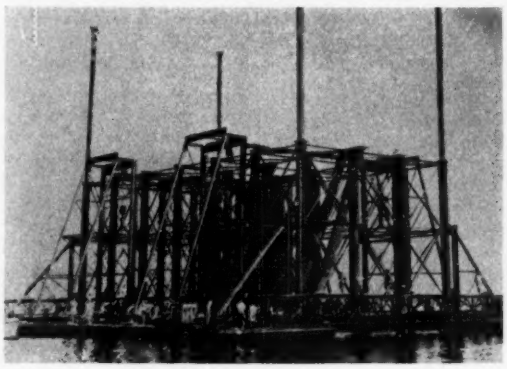


FIG 16

TRANSPORT OF JACKET FOR PLATFORM

PERSIAN GULF

An island which can be moved as a whole was made for use in the Persian Gulf, near the Qatar Peninsula.

From publications it was known that Aramco, after making a start in the Persian Gulf with large platforms, had subsequently taken to using a drilling tender, with which they still used rather large platforms. The Aramco field, however, lies rather near the shore and, after a provisional study of the meteorology and oceanography of the region in which the new Shell concession is situated, it was concluded that work with a separate barge for drilling equipment had to be considered out of the question. A general investigation of sea-bed conditions showed that the soil was exceptionally hard, although at some spots a comparatively thin layer of sand or mud (maximum thickness 2–3 ft) was present.

It was therefore decided to design a structure which

could stand on the sea bottom, and after some soil borings had been carried out it was found that the subsoil was so hard that great difficulties could undoubtedly be expected if piles were driven.

When placing the structure on the sea bed like a large table one certainly has to reckon with an uneven bottom, and therefore the piles may have to be of different lengths. Once a structure which stands on the sea bed has been designed it will be found desirable to make it capable of being moved easily, which implies that great differences in depths of water, which occur in the concession, have to be taken into account.

Near Qatar these depths vary from 16 to 180 ft. In order not to complicate the design it was decided that the first platform should be suitable for use in water not more than 100 ft deep.

The problem then was to design an island which could be easily moved, which could be used for drilling in sites covered by as much as 100 ft of water, and on which all drilling equipment could be placed. Originally it was the intention to anchor a sea-going vessel in the neighbourhood of the drilling site to accommodate the personnel. Even before the structure had been completed it became clear that it would not be possible to take the personnel off the island at any moment, and also that it was not advisable to have the vessel always lying in the open sea. It was therefore decided, during construction of the island, to build living accommodation for the personnel on it as well, whilst, after the island had been in use for some time, it was found that, especially in the case of great distances from island to base, which may exceed 60 miles, air transport had advantages over transport by water, so that now a helicopter deck has also been built.

After various construction possibilities had been investigated, preference was finally given to a steel structure built at the desired height above the water, whereby one could lower the legs to the bottom. This structure has been built on two lighters coupled to each other, which could be floated out from under the structure once the latter was standing on its own legs. The number of legs was fixed at eight. All this resulted in the design illustrated in Fig 17.

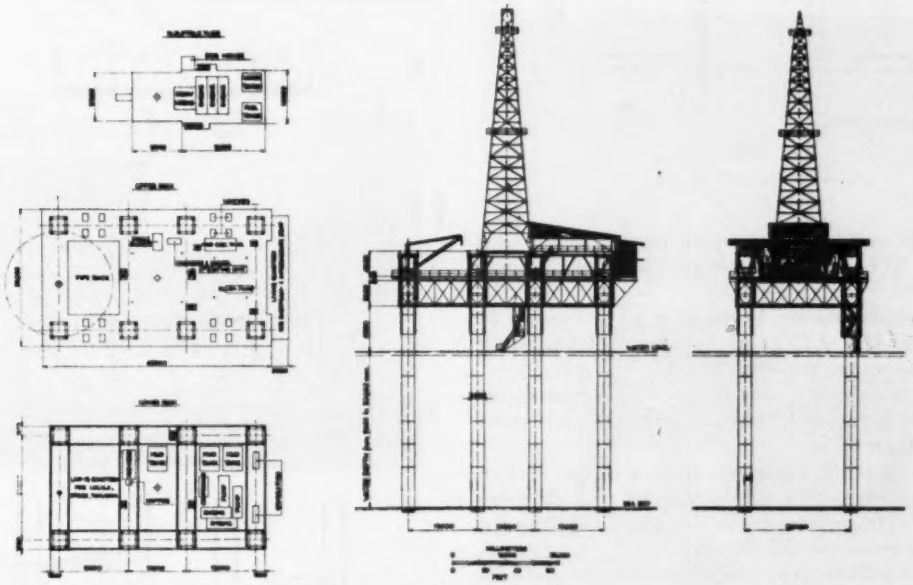


FIG 17

GENERAL ARRANGEMENT OF MOBILE DRILLING UNIT
(Qatar)

There are three floors, the lowest of which lies about 25 ft above water, the second 16 ft higher, and the third another 15 ft higher.

The legs are 8 ft square and are made wholly of sheets reinforced by T-beams (Fig 18).

A structure which is right out in the open sea is exposed to very strong wind and wave forces, and it was difficult to determine these. Very many meteorological data of the area were studied, and although from these it appeared that only once in a ten-year period had a wind of 65 m.p.h. occurred, winds of 100

m.p.h. were taken into account in the designing of the derrick, and winds of 85 m.p.h. as regards the other parts of the structure.

Furthermore, calculations showed that waves of heights up to 23 ft could occur. Data from ships

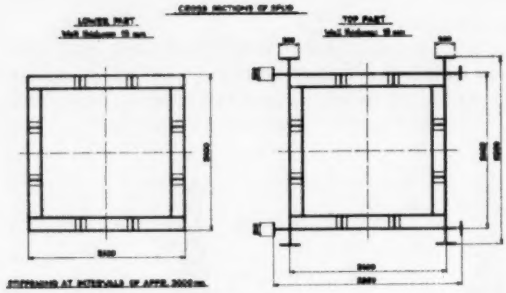


FIG 18

CROSS-SECTION OF SPUDS

since 1949 mentioned maximum wave heights of up to about 13 ft, but in the design a wave of 23 ft was adhered to.

The calculations are based on a wave force of 45 metric tons and of 70 metric tons in all on two spuds placed one behind the other.

Tests carried out in the Hydraulics Laboratory of Delft Technological University confirmed this order of magnitude.

It was intended to place the whole structure on two lighters which were firmly connected to each other and were provided with the necessary supports for the structure to rest on (Fig 19).

A great problem was how and where the platform was to be built. In Doha, the capital of the Peninsula, this was impossible without constructing a fully equipped harbour.

Basra or Bombay could not be considered either—apart from the question whether it would even be possible there—because the colossus would have had to be towed for some hundreds of miles.

However, in the bay of Doha, about 3–4 miles from the town, an island of somewhat elongated shape was found, which afforded good protection from the prevailing NW. winds; observations confirmed that under the lee of this island the wave action of the water was practically negligible. Consequently, in this place a crane with a capacity of 15 tons and a 120 ft jib was erected in the water.

With a view to reducing the work on the spot to a minimum, the steel structure was sent out in units which were as big as possible, making sure that no unit weighed more than 15 tons. These pieces were unloaded at Umm Said and carried to Doha by lighter, where they were stored on pontoons which were anchored near the crane. When shipment was effected, the sequence of assembly was taken into account as far as possible, so that on arrival the material could be erected without unnecessary delay.

The crane jib could not, of course, cover the whole platform, which therefore had to be regularly turned in order to ensure that the load on the barges on which the structure was built should be as uniform as possible. The structural parts sent out had been previously riveted or welded as far as practicable, and erection on the spot was carried out by means of bolts.

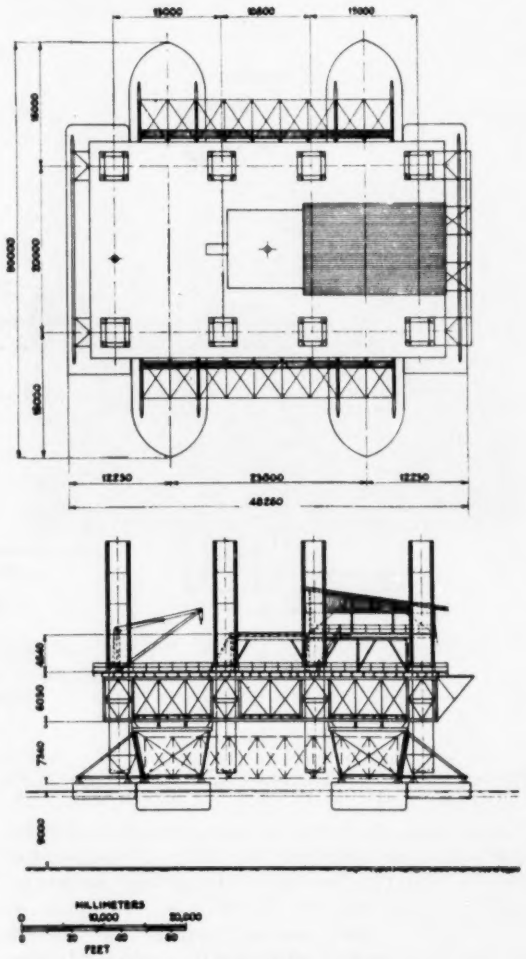


FIG 19

METHOD OF ERECTION AND TRANSPORT

A mock erection in the factory in Europe took place to ensure easy assembly at the site, and as a result of very precise preliminary work the unit could be assembled like a Meccano set.

Figs 20–22 give an idea of the dimensions of the whole structure.

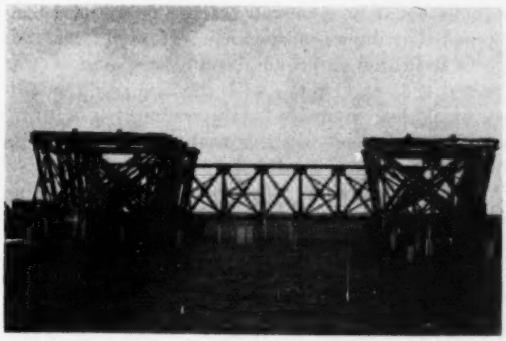


FIG 20
BARGES WITH FALSEWORK

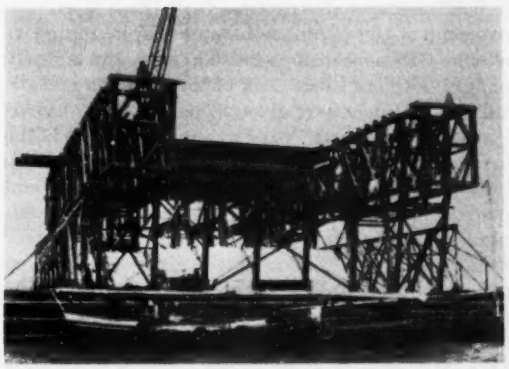


FIG 21
PLATFORM DURING ERECTION

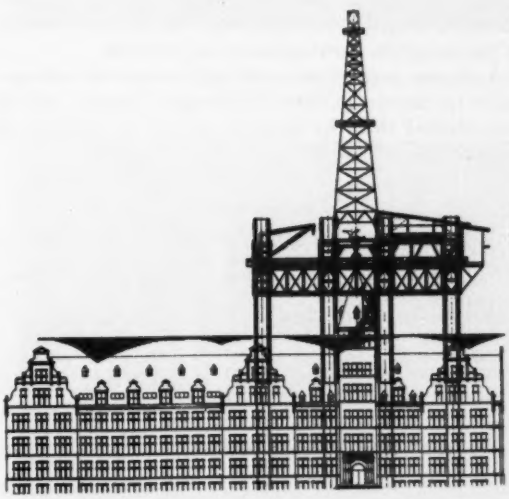


FIG 22
PLATFORM DIMENSIONS COMPARED WITH THOSE OF ROYAL DUTCH/SHELL HEAD OFFICE, THE HAGUE

The first drilling location was situated about 30 miles N. of Doha, and about 5 miles from the coast, the depth of the water being only 35 ft. In view of this, the full length of the legs (148 ft) was not fitted for this first site.

When the platform was anchored in its place, exactly on time (*i.e.* at high tide), the four inner legs were lowered to the bottom by means of hand winches, followed by the outer legs.

It was considered necessary to load the piles to the maximum load to be expected under working conditions before the platform was released from the barges, in order to prevent settling, owing, for instance, to the presence of a thin layer of sand, when the full load was exerted on the piles during drilling.

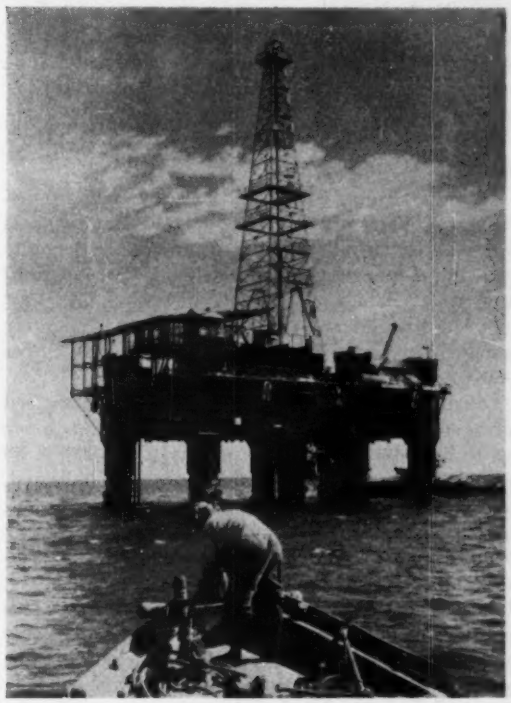


FIG 23
PLATFORM NEARING COMPLETION

A jacking system was therefore applied whereby four centrally-controlled hydraulic jacks could act on each leg, each jack having a capacity of 100 tons and a stroke of about 3 ft 6 inches. If, as was expected, the legs did not penetrate into the sea bottom, the barges, which during the operation were left under the platform, would act as springs drawn from the water, in the meantime transferring the weight of the platform to the legs (Fig 23).

In the reverse way the platform can be replaced on

the barges and the whole island moved, complete with drilling equipment.

Acknowledgement

This platform, which was designed in the offices of the Bataafsche Petroleum Maatschappij, The Hague, Royal Dutch/Shell Group Company, was fabricated by the Hollandsche Constructie Werkplaatsen at Leiden. Construction of the platform was carried out by George Wimpey & Co. Ltd., Hammersmith, London, and the placing was under supervision of Shell engineers. The platform was towed to the location by a 2000-h.p. tug of L. Smit & Co., Rotterdam, who had also been given the task of towing the two 1000-ton barges from Holland to Qatar. The thirty-two 100-ton jacks and double hydraulic pumps were supplied by Chamberlain Industries Ltd., London.

Loss of the Qatar Platform

After the drilling of exploration wells without success in two parts of the concession, the platform was to have been moved to Doha in order to incorporate some improvements before placing it on the third location.

During this operation the platform was irreparably damaged by rough seas on the night of 27 December 1956.

The drilling platform was supported on the sea bed during operation with eight spud legs. The move was to have been effected by means of two 220 × 30 × 15 ft pontoons, which were to have been ballasted, winched under the platform between the spud legs, and then pumped out. As the pontoons rose, a structural steel falsework on their decks would contact guides under the platform, lifting the latter, after which the spud legs could be raised. This operation had of necessity to take place in reasonably calm weather, and weather reports, including those from a weather ship stationed near Bahrain specially for this purpose, had to be taken into account for the timing of operations.

On the 27th lifting operations began under excellent weather conditions. The pontoons were inserted under the platform and began pumping out ballast. At 5 p.m. that afternoon, however, with the spud legs not yet retracted, the weather began to deteriorate. In view of this and the falling tide, it was decided to suspend lifting operations temporarily and to reballast the pontoons in case worsening conditions made it necessary to tow them out.

By 7 p.m. there was a 20-m.p.h. wind blowing and a 4-ft swell, and since it was doubtful whether the pontoons could be removed safely under these conditions, ballasting was suspended. However, weather reports indicated improving conditions, and it was expected that at 11 p.m., with the tide rising, conditions would be favourable for the resumption of lifting operations. Indeed, towards that time the wind fell to 10 m.p.h. and the swell began to lessen.

At 11 p.m., however, quite unexpectedly, a long, heavy, intermittent swell sprang up from the NE., which, superimposed on the prevailing NW. swell, gave rise to peak swells of about 8 ft. The effect of this swell was severe, badly shaking both pontoons and spud legs. The height of the swell made it impossible to maintain continuous contact between falsework and platform. The falsework soon became damaged through being battered against the bottom of the platform, and the cross-beams connecting the two pontoons were destroyed. Once these failed, the movement of the pontoons became still more uncontrollable; the pontoons pounded against and severely damaged both the lower deck of the platform and the spud legs. Orders were given to ballast the pontoons in order to tow them out, but, as it happened, the damage proceeded too rapidly to make this possible, efforts being obstructed by falling wreckage and damage to the falsework of the pontoons. By midnight lighting and radio had failed, and the helicopter platform collapsed. It became evident that nothing could be done to retrieve the situation, and personnel were evacuated from the platform at about 1 a.m.

The next day it was possible to see that, apart from severe structural damage to the spud legs and the platform itself, destruction of the lower deck floor beams had allowed two mud pumps and their engines to fall on the pontoons. The pontoons themselves ultimately capsized and were sunk in order to prevent further damage to the spud legs, which could result in the complete destruction of the platform.

As it was, a subsequent survey showed the damage to be too severe to allow of salvage or repair, and it was decided that the platform had to be considered a total loss.

Bibliography

[1] Cleary, E. *Engng News Rec.*, 26.12.40.
[2] *Petrol. Engr*, 1941, **12** (2), 165–8.
[3] Jansen, W. A., and Kranendonk, A. *Ingenieur, 's Grav.*, 23.6.50, **62** (25), M.41–7.
[4] *World Petrol.*, 1951, **22** (9), 32–3.
[5] Duff, D. M. *Oil Gas J.*, 8.11.51, **50** (27), 176–7.
[6] Payne, J. M. *Oil Gas J.*, 5.4.54, **52** (48), 102–4.
[7] Cox, H. D. API Paper No. 901–31–0, March 1955.
[8] Kemler, E. N., and Rosencrants, E. W. "Offshore Summary." Spring Park, Minnesota: Summary Reports, 1954.
[9] Journals: *Offshore*; *Offshore Drilling*.

DISCUSSION

B. F. Saurin: I would like to take this opportunity of acknowledging the help that BP staff received from Mr Kranendonk and his colleagues in Shell in many parts of the world during the studies made a couple of years ago for the Offshore Drilling Project in the Abu Dhabi Marine Areas section of the Persian Gulf. This Project is a combined operation of BP and the Compagnie Française des Pétroles, BP being the managing partner.

The Project offers similar difficulties to those of the Shell Qatar operation, made rather more severe by the total absence of any suitable base or harbour, both of which have had to be built for the purpose. The sea conditions are also somewhat more severe. A drilling platform of the DeLong type has been constructed in Germany and is now being towed to the Persian Gulf. Figs A and B show the main features of the platform, which comprises a pontoon 106 ft × 200 ft which can raise itself by means of hydraulic jacks on four legs 10 ft in diameter. A special feature called for by the bare limestone bottom of the Persian Gulf is a rubber-in-compression buffer incorporated in the connexion of each jacking yoke to the pontoon. Another is the mounting of most of the auxiliary machinery on deck, since it would be too hot to work inside the hull in Persian Gulf conditions.

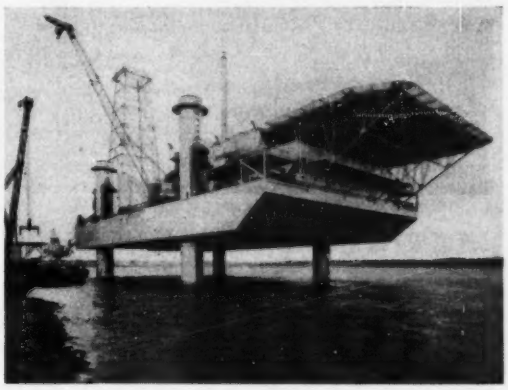


FIG A

Adma Enterprise WITH RETRACTABLE LEGS IN THE HIGH POSITION

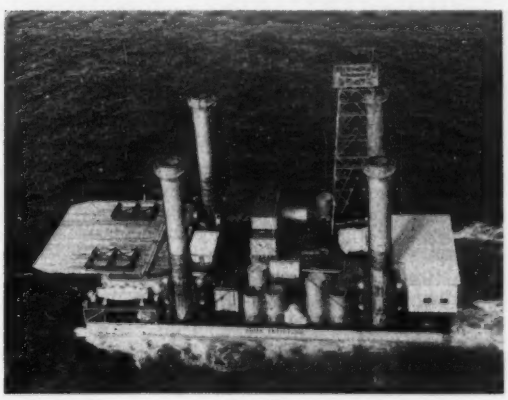


FIG B

Adma Enterprise EN ROUTE TO THE PERSIAN GULF

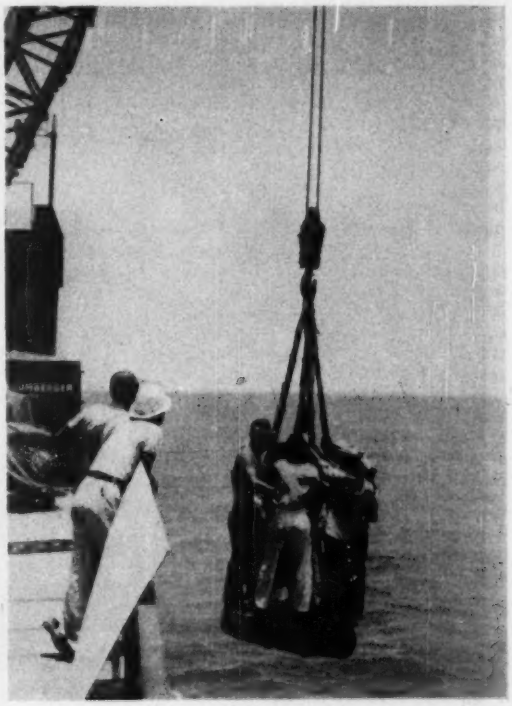


FIG C

HOISTING MEN ON TO A DRILLING PLATFORM AT QATAR

The other figures illustrate some matters of general human interest in connexion with drilling platforms, such as the methods employed for enabling the personnel to land on a drilling platform from a boat (Figs C and D). This has always been a difficult matter because an open structure gives no lee, and I would like to ask Mr Kranendonk what is the latest development in this connexion. On the Abu Dhabi Marine Areas platform men will be hoisted aboard from the boats by means of the crane provided for handling stores.

The complete lack of local facilities is illustrated by the picture of a small island in the Persian Gulf (Fig E), similar to that which has been adopted as a base for the Abu Dhabi Marine Areas operation.

Fig F gives a lively impression of the conditions at sea when 20-foot waves are running past a drilling platform.

A. Kranendonk: I do not know of better methods than were used on our Qatar platform. Nets such as BP will employ on their *Adma Enterprise* are widely used and it is proposed to adopt this method in the DeLong platform we are going to operate in Serie.

H. D. Fanshawe: In regard to storm conditions, it occurred to me that a derrick with 10,000 or more feet of pipe standing back in the fingers must have its centres of gravity and side-area some 60 ft above the rotary table.

Is this, in fact, a serious consideration when designing the platform? Or is it so large and heavy that the comparatively small weight of derrick and drill pipe becomes unimportant?

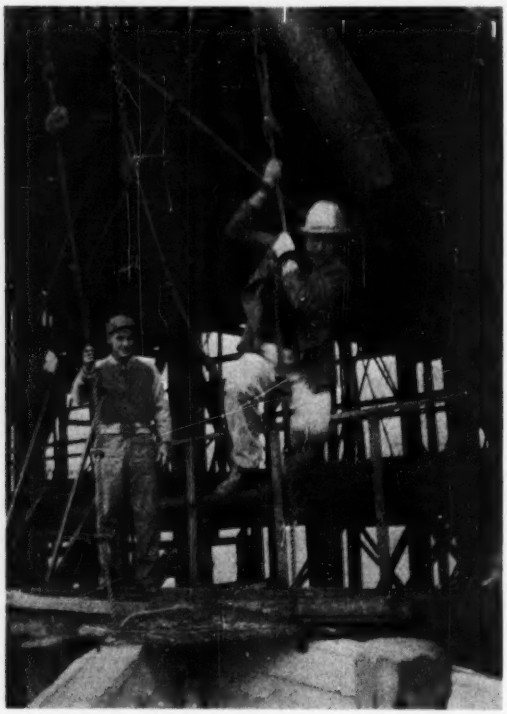


FIG D

ANOTHER METHOD OF LANDING ON A DRILLING PLATFORM

FIG E

SHURA AWA VIEWED FROM THE SOUTH

A. Kranendonk: The centre of gravity is in general not as high as 60 ft above the platform. The heavy weights are placed on the deck, and they have a large influence on the height of the centre of gravity.

In floating conditions the platform should have adequate stability. This is a question of calculation and of design of beam and draft of the floating platform.

Horizontal wind forces on these structures, even if they are applied fairly high above the platform, are not very dangerous on fixed platforms, as the influence of the horizontal forces is negligible compared with the very high vertical loads due to equipment. On a mobile platform wind forces should be considered in order to establish the preloading to be applied to the legs. There have been five or six turnovers in the Gulf of Mexico during the last few months, and they are all more or less due to extra load on the legs because of horizontal forces pressing some of them deeper into the bottom. However, for normal fixed platforms, with piles driven to refusal, these high structures do not provide any problems.

FIG F

20-FOOT WAVES RUNNING PAST A DRILLING PLATFORM

A. J. Ruthven-Murray: Is it possible for the author to give a few details about the spud piles? What are their O.D. and I.D.? Are they constructed of steel? Is any difference made to their bases for penetrating into silt without a hard bottom, or through sands, clays, or silts where a hard bottom is found?

A. Kranendonk: The majority of mobile platforms up to now have been designed for conditions prevailing in the Gulf of Mexico, where the subsoil consists of mud to a very great depth. It is difficult to predict how far they will penetrate and if one does not strike a hard layer the danger always exists that one of more of the spuds will give away during operations or during a storm. Legs penetrating into the soil may be made open-ended or with closed ends. Both methods can be used. Legs standing on a hard bottom should have closed ends for better distribution of the load.

B. F. Saurin: Are these spud structures of steel with a thick wall?

A. Kranendonk: Yes, all steel. If I am right the platform Mr Saurin showed has steel spuds of 10 ft in

diameter and up to 1¾ inches thick. When the Qatar platform was designed 8-ft square spuds were chosen. As there was no fixing point at the bottom of the legs, we could expect heavy bending moments at the top of the portal frames, and the square spud was considered to be the most suitable shape. Although there are objections to the square shape, we will have the same type of spuds in our second Qatar platform, which is now under construction.

W. E. Madden: Developing first the idea of a mobile platform in an area where it is necessary to drive piles, would it be practicable, when a move is required, to jettison the part of the pile which has penetrated the sea bottom, by means of some sort of back-off tool as used in drilling strings?

Secondly, the author left us with the idea of future drilling in very deep water from a floating platform. This is necessary, of course, where the shore shelves very rapidly, as off California, or in order to drill out to the edge of the continental shelf—the 100-fathom line. Could Mr Kranendonk give some idea of how the difficulties of drilling from a floating platform can be overcome? For instance, the vertical movement of the platform under the influence of waves would presumably call for a device to keep the bit constantly on bottom. Similarly, it would seem that there might be difficulty in finding the hole again after pulling out to change a bit, and so on.

A. Kranendonk: Jettisoning part of the piles is too expensive a method. The weight of the spud parts is very high, and assembling of the spuds is a very time-consuming job which cannot be allowed after each hole. These platforms cost approximately $8000–9000 a day, so we should not lose weeks in changing spud parts.

However, in fact this is not necessary, as experience has taught that it is almost easier to extract the legs than to push them into the soil.

In regard to Mr Madden's second question I would say that we are as interested in all these problems as he is. Unfortunately I cannot tell too much of it. A lot has been done on the Californian coast, but I understand that the main features cannot be disclosed pending the application of various patents. It is, however, known that this method is used only for exploratory purposes, and so far no wells have been drilled which have been brought into production.

E. Ingerslev: Can the author give any idea of the method of construction of these spuds? How does one get them in? Are they pressed in simply by the weight of the platform, or are they rammed in?

A. Kranendonk: Spuds are spudded in by means of hydraulic jacks. In the initial stages air jacks have been used, but now the hydraulic system is generally applied. In the Le Tourneau platform use is made of rack and pinions driven by electric motors.

A. J. Ruthven-Murray: When Creole used caissons in Lake Maracaibo these were not driven, but pressed down like pushing a pencil through butter until refusal was met, using a load of 200 tons per caisson.

A. Kranendonk: This can be done if there is a soft layer on top of a hard one, as there is in Lake Maracaibo. It is, however, difficult when applying this method to penetrate the harder layer, and therefore I do not like it. There should be a certain relation between the thickness of the mud layer and the water depths, otherwise this method is not to be recommended. Creole have not used this caisson foundation in the deeper waters (say, over 70–80 ft) and are now using structures made of solid concrete piles.

We have made tests with hollow post-stressed concrete piles in Lake Maracaibo which have been driven, as we wanted the piles to penetrate into the hard layer. During driving, however, cracking often occurred due to various reasons.

C. T. Reichert: I can say that the offshore operations in California in the floating barges are extremely interesting. There are nine or ten such barges, one of which is the Shell group already mentioned. This, incidentally, is fitted with heavy equipment fully capable of going to 10,000 ft without any difficulty, which has made substantial footage. The fact is that the Shell group operations are closely guarded as far as giving out information is concerned.

However, that is the largest unit; the others, of which there are eight or nine, are used mainly for geophysical work, but they are capable of going below 4000 ft in their drilling.

As far as pulling away from the hole is concerned, it is quite easily done; they can pull away, and come back next day or a week later. They use underwater television as a means of enabling the controller of the barge to know whether they are exactly over the spot or not. The barges are anchored generally from four corners, so that once they are set, they hold their position very well. Naturally, there is a tremendous amount of flexibility in drill pipe, and on the geophysical rigs the drill pipe is small, say, 3½ inches, and it will stand quite a bit of flexing. As far as the rise and fall of the waves are concerned, there is a sliding joint used, which does keep the bit on the bottom, even though the vessel rises and falls with the waves.

It is a most interesting operation and I have heard some of the men who have had a lot of experience in the Gulf of Mexico say that they think it very likely that the floating type of device may be the one that is used for deep water. Companies which have floating barges in operation, including the Shell group, seem to be very well pleased. I spent the last day before I left California on one of these vessels, and the figures I was given were that 15,000 ft of hole per month can be drilled very easily and that the drilling rate can be maintained without any great difficulty. Of course, their big saving is that when they move it is an easy job to be towed to another location, a mile or so away, and start drilling again almost immediately.

G. McDowell and J. E. Innes: We would like to ask a question about these hydraulic (lifting) jacks with the platforms. We wonder whether the author has anything similar in mind for pressures applied horizontally by the waves, *i.e.* if one could transpose that hydraulic pressure against those "enormous forces due to drilling" or lifting which may tend to push the platform out of alignment. In other words, since there must be a restricted cantilever from the sea bed, this effect will give rise tc lateral movement at the top. Mr Kranendonk has already spoken about the action of waves and wind and there must be a large force tending to overturn the foundation. Is there any means of providing an hydraulic effect which would right that? (See Fig G.)

A. Kranendonk: Hydraulic effect to withstand horizontal force?

G. McDowell: Yes. To counteract the overturning tendency of forces due to pressure of waves and wind.

A. Kranendonk: Horizontally?

G. McDowell: Yes, that is what we have in mind. Could that horizontal force be transferred vertically as

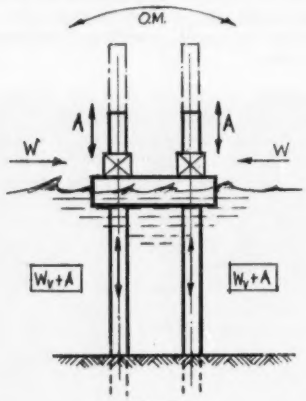


FIG G

A = Vertical lifting and lowering forces due to jacks only;
W = Lateral forces due to wind and wave action;
O.M. = Overturning moment.
$W_v + A$ = Counterbalancing forces against O.M.

(Queried possibility of additional restraint by hydraulic aid to lifting jacks)

in a hydraulic jack when it is working or operating, to attempt to correct any lateral movement.

A. Kranendonk: I have never heard of any device which would do that, and I do not think it is necessary to use the horizontal forces for that purpose, as lateral movement of the platform during operation is negligible if it is well designed and the legs have been sufficiently preloaded.

H. D. Fanshawe: I would like to ask Mr Kranendonk if, when he is asked to produce a platform, whether it must be the equivalent of a land base for a normal rig? Or is he free to specify modifications to the drilling equipment which will fit it for the special case of his design of the platform or barge?

A. Kranendonk: Normally, similar equipment to that used on a land base will be used on a marine location.

H. D. Fanshawe: I was thinking in particular of the platform design which you used for Doha. For instance, seeing that it is built on three levels, I was rather surprised that the base of the derrick proper was mounted on the highest level of all. One might have expected that the derrick would have been based on the lowest level to keep its centre of gravity as low as possible, and the other equipment adapted so that it could be built up round the derrick.

A. Kranendonk: The situation of the pipe rack is more or less fixed. To facilitate supply of drill pipe and casing to the pipe rack it should be easily accessible with a crane. The drilling floor has to be higher than the pipe rack and once the place of the pipe rack is chosen, the drilling floor and the position of the drawworks on that floor are fixed. If the rig is diesel-driven the place of the drawworks determines the position of the engine and then the placing of the mud pumps is also fixed. From this it may be clear that the lay-out of a diesel mechanical rig always follows a firm pattern from which only minor deviations are possible. If a diesel electric rig is used the lay-out of the drilling platform can be simplified but the drilling floor will remain at the highest level. As already mentioned, this has little influence as regards wind forces.

H. D. Fanshawe: With the enormous capital and daily running costs of an offshore platform, is it justifiable to use much more elaborate automatic equipment than on land, so as to save minutes in round-trip time, etc.?

A. Kranendonk: I do not think so. The main costs of the unit are during drilling and saving in drilling time will have a greater influence than the time saved on lowering and lifting the unit. Therefore it is very important to have a very good lay-out when designing a unit, and this is the most difficult problem.

One of the things I do not like about the *Adma Enterprise* is that the hull of the vessel is completely empty. When I saw all that room I thought that it was an excellent space in which to put materials and spare parts. The danger is that by filling this space the total weight of the unit increases beyond the lifting capacity of the jacks.

J. W. Baxter: This idea of an artificial island floated into position is a very intriguing one, but I think the paper rather gives the impression that it is an idea which originated across the Atlantic and, as so many ideas do originate across the Atlantic, I think it is important when one originates in Europe that the point should be made.

There was a scheme about 40 years ago for setting a chain of artificial islands right across the Channel to stop German submarines coming out. It was not carried out because the war finished too soon, but one of them was actually built and floated out and used as a base for a lighthouse near Southampton, the Nab light.

Other early examples of artificial islands were the anti-aircraft and naval forts which were set in the sea around Britain during the second world war. They were designed by G. A. Maunsell and were floated out complete and set down on the sea bed. They were not mobile, but the idea used in those forts was developed subsequently and is in use now in the movable boring tower which the National Coal Board is using in the Firth of Forth.

E. J. Sturgess: I noticed that on the Qatar platform the 8-ft square legs were lowered by hand winches. Is this going to be repeated? It seems a rather laborious process.

A. Kranendonk: No. Originally it was intended to replace these hand winches by electrical winches.

E. J. Sturgess: One other point is the question of corrosion. There has been some extremely heavy corrosion, especially in Persian Gulf waters. What special steps have been taken in that direction?

A. Kranendonk: There was excellent cathodic protection on the Qatar platform and we had no corrosion at all. After the first move, when the legs had been in the water for more than 11 months, the first painting was still completely intact.

A vote of thanks to the author was accorded with acclamation.

HYDROCARBONS FROM PETROLEUM *

By FREDERICK D. ROSSINI †

I PROPOSE to summarize the results of that part of the work of the American Petroleum Institute Research Project 6 pertaining to the composition of petroleum. Before going into that directly, however, I would like to report on some historical aspects of petroleum, particularly as looked at from the U.S.A.

Although petroleum contains small amounts of sulphur, nitrogen, and oxygen compounds, it is largely hydrocarbon material and contains molecules ranging from 1 to 50 or more carbon atoms per molecule in size, comprising a diversity of molecular types.

Going back into history, we find that early man wondered about the thick dark liquid that oozed from the earth in certain places, or floated on natural waters. He learned that this strange substance would burn and give out great heat and light. Petroleum, or some portion thereof, is mentioned in the Bible, and records show that asphalt was used by man as early as 3800 B.C.

Petroleum was found as an oily liquid exuding from the surface of the earth in the form of tar springs, or rising from springs beneath the beds of rivers, or floating on water. In the latter case it might appear as a thin film with the familiar rainbow colours, or perhaps as dark globules which could be separated mechanically. In these forms, and these rather limited amounts, petroleum was found in relatively many places on earth, notably Rumania, Persia, Italy, Cuba, Trinidad, India, and later, the U.S.A. In W. Pennsylvania an enterprising business man by the name of Kier collected this petroleum, put it in bottles labelled " Kier's Rock Oil," and sold it as a medicine for the cure of many different human ills.

The story of the first petroleum company is told in a number of ways, and here is one version of it, from P. H. Giddens. In 1853, a young lawyer of New York City returned on a visit to his old home in Hanover, New Hampshire. There, in the office of the Department of Chemistry at Dartmouth College, he saw on the shelf a small bottle of petroleum that came from an oil spring on a farm in NW. Pennsylvania. On his return to New York, he discussed the commercial possibilities with his lawyer partner, who also became interested. They discussed with some bankers from New Haven, Connecticut, the formation of a company to purchase this farm and market the rock oil obtained from the tar springs there. The bankers, however, did not wish to go into this blindly, and felt that they first had to have a scientific analysis made of the petroleum. The lawyers engaged for this purpose the services of one of the U.S.A.'s then most famous scientists, Professor Benjamin Silliman, Jr., of Yale College. In the meantime, the two lawyers proceeded to look at the farm in NW. Pennsylvania, inspected the oil springs, and arranged to purchase the farm. In December 1854 they organized the world's first petroleum company, called " The Pennsylvania Rock Oil Company of New York." The company found it difficult to sell stock in the new venture, because very few people knew anything about petroleum and its potential value or commercial possibilities. However, Professor Silliman's report, which came out in April 1855, was the turning point. Professor Silliman placed his report in the hands of a friend in New York City, with instructions not to deliver the report to the two lawyers until they had made satisfactory arrangements to pay Professor Silliman for his services in the exact amount of $526.08. They managed to gather the money to pay his bill, secured the report, and had copies of it printed. So there came to be available printed copies of what is the first scientific analysis of petroleum. This was the turning point in the commercial venture.

The cover page of Silliman's report reads: " Report on the rock oil or petroleum from Venango County, Pennsylvania, with special reference to its use for illumination and other purposes, by B. Silliman, Jr., Professor of General and Applied Chemistry, Yale College."

On p. 5 is a section headed " General Characters of the Crude Product," in which he tells of the properties of this crude petroleum, as follows:

> " The crude oil as it gathered on your lands has a dark brown colour, which by reflected light is greenish or blueish. It is thick even in warm weather, about as thick as thin molasses. In very cold weather it is somewhat more stiff, but can always be poured from a bottle, even at 15° below zero. Its odour is strong and peculiar and recalls to those who are familiar with it the smell of bitumen and naphtha. Exposed for a long time to the air, it does not thicken or form a skin on its surface, and in no sense can it be called a drying oil. The density of the crude oil is 882, water being taken as 1000. It boils only at a

* Address given at a meeting of the Institute of Petroleum, 9 July 1957.

† Silliman Professor and Head, Dept. of Chemistry, Director, Chemical and Petroleum Research Laboratory, Carnegie Institute of Technology, Pittsburgh 13, Pennsylvania.

very high temperature, and yet it begins to give off a vapour at a temperature not greatly above that of boiling water. It takes fire with some difficulty and burns with an abundant smoky flame. It stains paper with the appearance of ordinary fat oils and feels smooth and greasy between the fingers. It is frequently used in its crude state to lubricate coarse machinery. In most chemical characters it is entirely unlike the fat oils. Most of these characters are common to petroleum from various places."

Then the report discusses examination of the oil, its fractional distillation, density of some of the fractions, properties of the distilled oils, use for gas making, distillation at a higher temperature, distillation by high steam, use of the naphtha for illumination, the results of some photometric experiments in connexion with the use for illumination, and use of the rock oil as a lubricator for machinery. Finally, come a few words:

"In conclusion, gentlemen, it appears to me that there is much ground for encouragement in the belief that your company have in their possession a raw material from which by a simple and not expensive process they may manufacture very valuable products. It is worthy of note that my experiments prove that nearly the whole of the raw product may be manufactured without waste, and this solely by a well-directed process which is in practice one of the most simple of all chemical processes. Now there are suggestions as to the economy of your manufacture, when you are ready to begin operations, which I shall be happy to make, should the company require it. Meanwhile, I remain, gentlemen, your obedient servant, B. Silliman, Jr., Professor of Chemistry at Yale College, New Haven, Connecticut, April 16, 1855."

Four years later, in 1859, came the completion of the famous Drake well, the first drilled petroleum well in history. This well was drilled to a depth of 69½ feet, and produced approximately 25 barrels of petroleum a day, which then was an enormous production.

Prior to about 1900, the refining of petroleum consisted essentially in using the process of simple distillation to produce the fractions which we now call gasoline, kerosine, gas oil, and lubricating oil, and most of the early use of petroleum was of the kerosine for illumination and of the lubricating oil for lubrication. In those early days, the gasoline fraction was a drug on the market, and, because of its volatility, the physical disposal of this excess material posed a real and hazardous problem. After about 1900, however, there was no longer any worry about what to do with the gasoline because more and more of it was needed to operate the increasingly great number of automobiles appearing on American highways, and soon there even came to be a shortage of gasoline in terms of how much could be got from a barrel of petroleum. Fortunately, about the time of the first world war, there came into use in the petroleum industry the cracking process, which resulted in a greater percentage of a barrel of petroleum being converted into gasoline.

After the first world war the U.S. petroleum industry began to be seriously concerned about the composition of this raw material. It was quite clear

FIG. 1

SITE OF BRETT WELL NO. 6, NEAR PONCA CITY, OKLAHOMA, AFTER THE WELL WAS PLUGGED AND ABANDONED BECAUSE OF SALT-WATER ENCROACHMENT

that increasing fundamental knowledge of this mixture of chemical compounds that constituted petroleum would lead not only to a more economical use of the petroleum in the existing processes, but also would lead to the production from petroleum of many new substances that would have great value. It was in 1925 that the petroleum industry, through the API, embarked on a programme of fundamental research on the origin, recovery, composition, and properties of petroleum. The purpose of this programme was to obtain fundamental, basic, and background information concerning petroleum which would benefit the industry as a whole in fields of broad, but primarily non-competitive interest, and would not be directly applicable to any industrial operations as such.

Among the many API research projects established at that time was the API Research Project 6, which is now in its thirty-first year of continuous operation.

Fig 1 shows a historical picture from the records of the API Research Project 6. This picture, taken in March 1940, shows the location, at the spot marked X, of the Brett No. 6 well in the Ponca City field, Oklahoma. It was from this well that a quantity of 500 gallons of original crude petroleum was taken in 1928 for the API Research Project 6. The Project has had this petroleum continuously under investigation ever since.

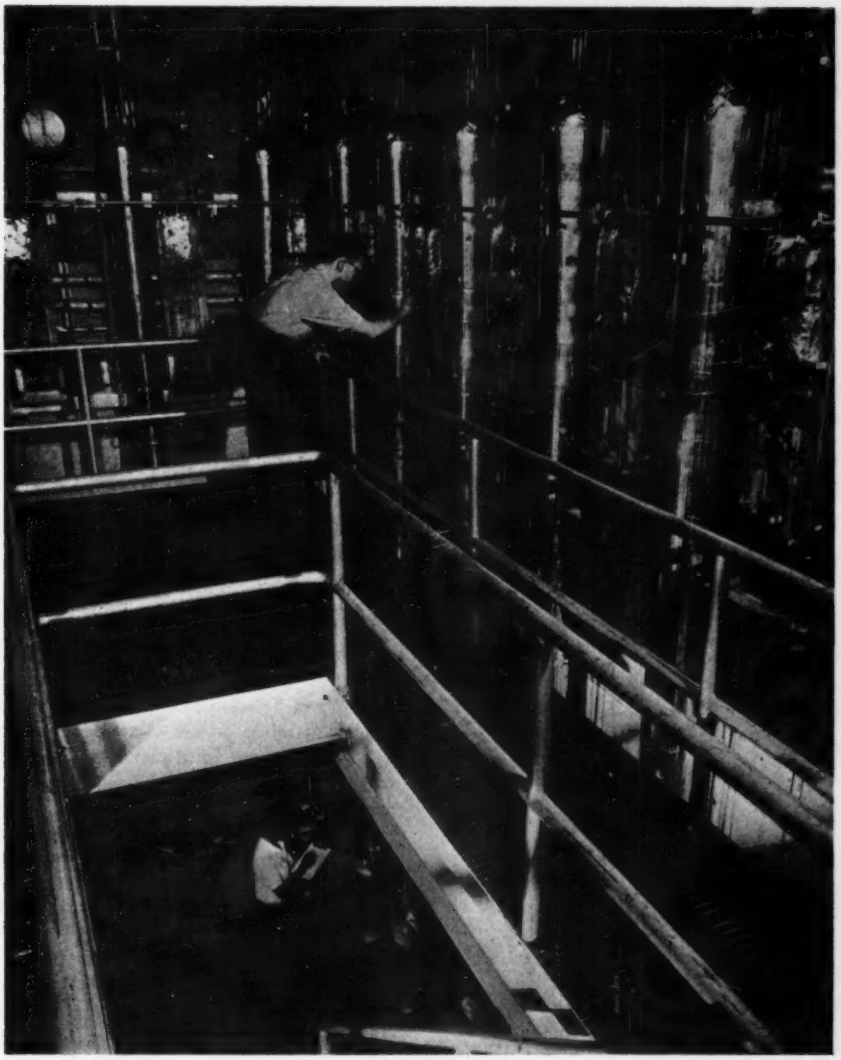


FIG 2

VIEW IN DISTILLATION LABORATORY OF API RESEARCH PROJECT 6

The four main lines of investigation of the API Research Project 6 are as follows:

(1) Fractionation, analysis, and isolation of hydrocarbons from petroleum.

(2) Development and operation of fractionating processes, for fractionating hydrocarbons.

(3) Purification and purity of API Standard and Research hydrocarbons for identification of hydrocarbons from petroleum and for spectrometer calibration.

(4) Measurement of physical properties of high purity hydrocarbons for record and identification.

The main fractionating processes used in this work of the API Research Project 6 are as follows:

(1) Distillation (involving a liquid phase and a gas phase)—

(*a*) Regular, at one pressure (at 30, 55, 214, and 760 mm mercury).

(*b*) Alternately at different pressures (at 30, 55, 214, and 760 mm mercury).

(*c*) At very low pressures (0·01 to 0·1 mm mercury).

(*d*) Azeotropic (with regular polar organic compounds or with fluoro-chemicals as added components).

(2) Extraction (involving two liquid phases)—

(*a*) With one solvent phase.
(*b*) With two solvent phases.

(3) Adsorption (involving a liquid phase and solid-adsorbed phase)—

(*a*) Regular.
(*b*) With one or more added components.

(4) Crystallization (involving a liquid phase and a solid phase)—

(*a*) Regular.
(*b*) With selected solvent.

(5) Formation of solid molecular or clathrate compounds.

Among the foregoing fractionating processes, separation by size of molecules is produced by distillation

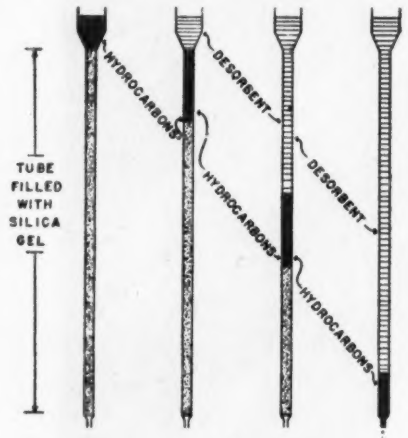


FIG 3

SCHEMATIC DIAGRAM OF THE SIMPLE FRACTIONATING PROCESS OF ADSORPTION

at one fixed pressure, whereas separation by type of molecules is produced by distillation alternately at different pressures, distillation azeotropically, extraction, and adsorption.

Fig 2 shows a view of the distilling laboratory. This is a two-storey room, in which there are thirteen complete distilling assemblies, operating continuously 24 hours per day, seven days per week. Adjoining rooms on each level provide the operating space. When columns have a separating power equivalent to 200 theoretical plates, with charging capacities of 0·5 to 15 litres, and are operated at a reflux ratio of 200 : 1, the times of distilling given charges may be as short as two weeks, averages one to two months, and may be as long as six months.

Fig 3 shows a schematic diagram of the simple fractionating process of adsorption. The desorbent (ethyl alcohol) forces the zone of hydrocarbons (shown in solid black) down over the solid adsorbent (silica gel). As the zone of hydrocarbons passes down

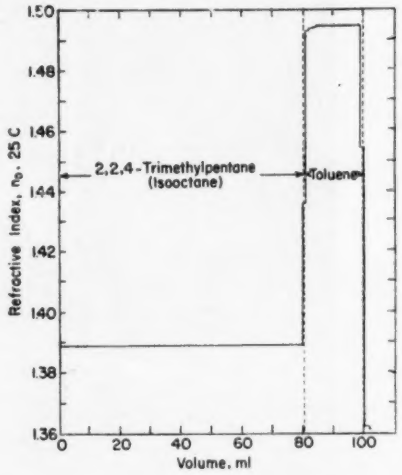


FIG 4

SEPARATION OF TOLUENE AND 2,2,4-TRIMETHYLPENTANE ("*iso*OCTANE") BY ADSORPTION

over the adsorbent, those hydrocarbons which are more strongly adsorbed lag behind, while those which are less strongly adsorbed are pushed forward and are the first to issue from the bottom of the adsorption tube. In actual practice, apparatus of this kind ranges in size from Pyrex-glass tubes $\frac{3}{8}$-inch in diameter and 3 feet in length up to stainless steel tubes 2 inches in diameter and 70 feet in length.

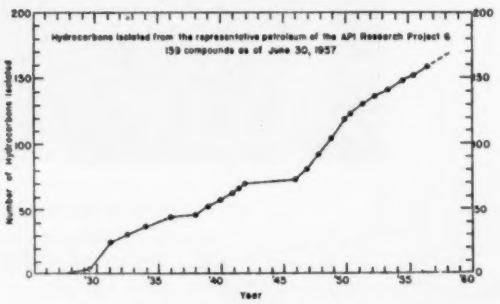


FIG 5

RATE AT WHICH HYDROCARBONS HAVE BEEN ISOLATED FROM PETROLEUM BY API RESEARCH PROJECT 6

One of the small glass adsorption columns can be used to determine the amount of aromatic hydrocarbons in a sample of gasoline. The results of the separation by adsorption of a test mixture made up of 20 ml of toluene and 80 ml of 2,2,4-trimethylpentane ("*iso*octane") is shown in Fig 4. The separation is seen to be quite sharp.

Fig 5 shows the rate at which new hydrocarbons

TABLE I

Distribution, by Type and Boiling Range, of the Hydrocarbons Isolated from One Representative Petroleum by the API Research Project 6 as of 30 June 1957

Type of compound	Fraction				
	Gas and gasoline to 180° C (C_1 to C_{10})[a]	Kerosine 180° to 230° C (C_{11} to C_{12})[a]	Light gas oil 230° to 300° C (C_{13} to C_{17})[a]	Heavy gas oil and light lubricating distillate (C_{18} to C_{22})[a]	Total
	Number of compounds				
Normal paraffins	10	2	4	8	24
Branched paraffins	37	—	—	—	37
Alkyl *cyclo*pentanes	22	—	—	—	22
Alkyl *cyclo*hexanes	13	—	—	—	13
Alkyl benzenes	20	20	—	—	40
Alkyl *cyclo*heptanes	1	—	—	—	1
Bi*cyclo*paraffins	4	2	—	—	6
Dinuclear aromatics	—	1	6	1	8
Aromatic *cyclo*paraffins	1	6	1	—	8
Total	108	31	11	9	159

[a] Approximate.

have been isolated from the representative petroleum of the API Research Project 6, using the fractionating processes in appropriate sequence. The numbers begin with zero in 1927 and rise to 159 as of 30 June 1957. The horizontal position of the curve near the middle corresponds in time to the second world war, when the resources of the Project were largely diverted to work on military aviation fuels and related problems. It is hoped that the total number may be 170 by the centennial celebration of the Drake well in 1959.

Table I gives the distribution, by type and boiling range, of the 159 hydrocarbons isolated to date.

Table II gives the distribution, by type of compounds and numbers of carbon atoms per molecule, of the 159 hydrocarbons isolated.

Table III gives a summary of the amount of the representative petroleum, and of its principal fractions, constituted by the 159 hydrocarbons isolated.

Fig 6 shows the relative amounts of the several classes of hydrocarbons in the broad fractions of petroleum.

That part of the gasoline fraction of petroleum normally boiling between 40° and 132° C is substantially made up of sixty-five compounds. In Fig 7 the vertical scale gives the percentage amount of this material that is constituted by any given number of the sixty-five hydrocarbon compounds, with the number being counted in increasing order of occurrence, the most abundant compound being counted first, the next most abundant second, etc. As this plot shows, this gasoline material is not nearly so complex as it might have been. Five compounds constitute nearly 50 per cent of the material.

Fig 8 gives a similar plot for the entire gasoline fraction of petroleum, taken as the material normally boiling between 40° and 180° C. Here it is seen that although there are about 500 compounds possible in the entire gasoline fraction, the bulk of the material is made up of a relatively small number of compounds. 15 compounds constitute 52 per cent of the entire material. The dashed line is what we would have if Nature had made each of the 500 possible compounds occur in equal amounts in this gasoline.

Table IV shows the four bi*cyclo*paraffin hydrocarbons isolated from the gasoline fraction of petroleum. These bi*cyclo*paraffins are present in petroleum in very small amounts. It is interesting to note that the third bi*cyclo*paraffin listed, bi*cyclo*-[3,2,1]-octane,

TABLE II

Distribution, by Type of Compounds and Number of Carbon Atoms per Molecule, of the 159 Hydrocarbons Isolated as of 30 June 1957

Type of compound	Number of carbon atoms per molecule																							Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Normal paraffins	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24
Branched paraffins				1	1	4	6	15	7	3															37
Alkyl*cyclo*pentanes					1	1	5	13	2																22
Alkyl*cyclo*hexanes						1	1	8	3																13
Alkylbenzenes						1	1	4	8	22	4														40
Alkyl*cyclo*heptanes							1																		1
Bi*cyclo*paraffins								3	1	1	1														6
Dinuclear aromatics										1	2	2	1	1											8
Aromatic *cyclo*paraffin									1	4	3														8
Total	1	1	1	2	3	8	15	44	23	32	11	4	2	2	1	1	1	1	1	1	1	1	1	1	159

TABLE III

Summary of the Amount of the Representative Petroleum Constituted by the Hydrocarbons Isolated as of 30 June 1957

Fraction	Approximate boiling range, °C	Estimated percentage of the original petroleum constituted by the given fraction	Number of compounds isolated	Estimated percentage of the fraction accounted for by the hydrocarbons isolated	Estimated percentage of the original petroleum accounted for by the hydrocarbons isolated
Gas and gasoline	to 100	37·2	108	85	31·5
Kerosine	180–230	13·1	31	35	4·6
Light gas oil	230–300	17·1	11	35	6·0
Heavy gas oil and light lubricating distillate	300–400	15·6	9	15	2·4
Lubricant fraction	—	10	—	—	—
Residue	—	7	—	—	—
Total petroleum	—	100	159	—	44·5

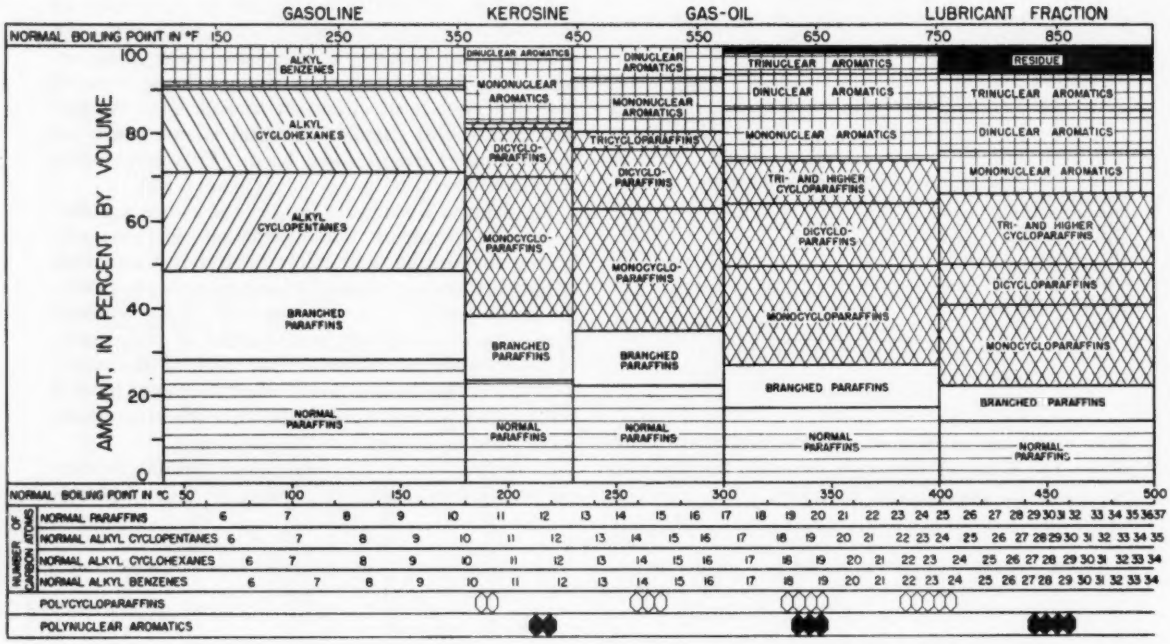


Fig 6

RELATIVE AMOUNTS OF DIFFERENT TYPES OF HYDROCARBONS IN SEVERAL BROAD FRACTIONS OF ONE REPRESENTATIVE PETROLEUM

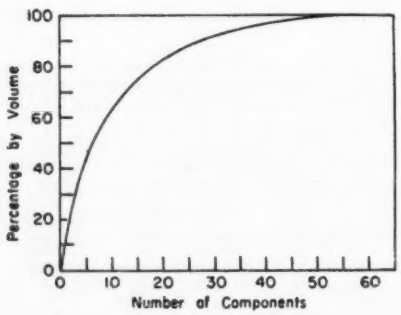


Fig 7

RELATION BETWEEN THE NUMBER OF COMPONENTS IN THE LIGHT GASOLINE FRACTION, 40° TO 132° C, AND THE PERCENTAGE OF THIS FRACTION CONSTITUTED BY THEM

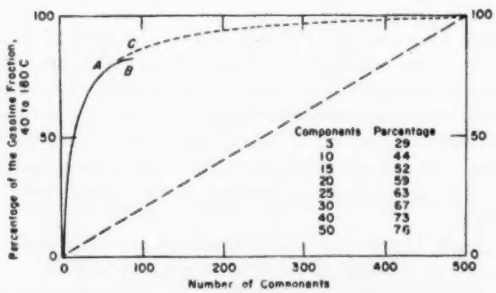


Fig 8

RELATION BETWEEN THE NUMBER OF COMPONENTS IN THE GASOLINE FRACTION, 40° TO 180° C, AND THE PERCENTAGE OF THIS FRACTION CONSTITUTED BY THEM

has a freezing point 3° C above the temperature of the boiling point of the narrow-boiling petroleum fraction from which it was isolated.

TABLE IV

Four Bicycloparaffin Hydrocarbons Isolated from the Gasoline Fraction of Petroleum

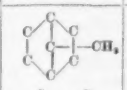
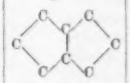
Name	Formula	Schematic structure	Boiling point 1 atm, °C
(Methyl-[2,2,1]-bicycloheptane) .	C_8H_{14}		124·5
Cis-bicyclo-[3,3,0]-octane . .	C_8H_{14}		136·5
Bicyclo-[3,2,1]-octane . . .	C_8H_{14}		138
Bicycloparaffin	C_9H_{16}		146·7

Table V shows a series of possible nuclear structures of the bicycloparaffins that it is believed will be the ones to be found in petroleum. Each of the structures is characterized by having five or six or seven carbon atoms in each ring.

TABLE V

Structures of the Nuclei of Bicycloparaffin Hydrocarbons Believed to be Present in Petroleum

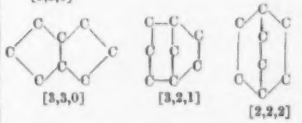
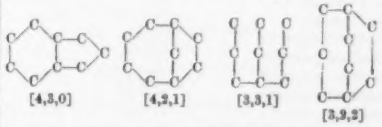
Class	Structure of the nucleus
Bicycloheptanes .	[2,2,1]
Bicyclooctanes .	 [3,3,0] [3,2,1] [2,2,2]
Bicyclononanes .	 [4,3,0] [4,2,1] [3,3,1] [3,2,2]

Table VI summarizes the occurrence of all *cyclo*paraffins in the several broad fractions of petroleum. It is interesting to note that the percentage amount of all *cyclo*paraffins is substantially the same in all the broad fractions.

Table VII gives a list of the 159 hydrocarbons isolated as of 30 June 1957, including the numerical number (in order of ascending boiling point) of the given compound, the molecular formula, name, and type of the compound, the boiling point at 1 atmosphere, the purity of the best sample isolated, and the estimated amount of the given compound in the original crude petroleum.

TABLE VI

Amounts of cyclo*Paraffins in the Several Broad Fractions of the Project's Representative Petroleum*

Type	Kerosine 180° to 230° C (C_{10} to C_{12})[a]	Light gas oil 230° to 300° C (C_{12} to C_{17})[a]	Heavy gas oil and light lubricating distillate (C_{15} to C_{25})[a]	Lubricant fraction C_{25} to C_{34}[a]
	Percentage by volume of the given fraction constituted by the given type			
Monocycloparaffins .	33	28	22	18
Bicycloparaffins .	11	14	14	10
Tri- and higher cycloparaffins . .	—	4	11	17
Total . .	44	46	47	45

[a] Approximate.

About 1940, the Advisory Committee for the API Research Project 6 decided that, having learned a great deal about the hydrocarbons in one representative petroleum, the Project should gain some knowledge of how petroleums from different fields varied. The Project's one representative petroleum, from Oklahoma, was intermediate in type. The gasoline fractions from six additional representative petroleums were selected to represent large production in different areas of the country and to be as different as was known at the time. The seven representative gasolines are listed together in Table VIII. By means of an extended but relatively short-cut procedure involving the fractionating processes of distillation and adsorption, analyses were made of the major components in these seven gasolines. From this work, the following conclusions were reached:

(1) All petroleums contain substantially the same hydrocarbon compounds.

(2) The principal compounds in the gasoline fraction of each petroleum may be placed in five main classes—

(*a*) Normal (straight-chain) paraffins
(*b*) Branched paraffins
(*c*) Alkyl *cyclo*pentanes
(*d*) Alkyl *cyclo*hexanes
(*e*) Alkyl benzenes

(3) Within each of these five classes, the individual compounds occur in proportions which are usually of the same order of magnitude for different petroleums.

Table IX gives the relative amounts of the 40° to 102° C fraction of the seven representative petroleums constituted by the five principal classes of hydrocarbons in the gasoline fraction.

TABLE VII

Hydrocarbons Isolated from One Representative Petroleum by the API Research Project 6 as of 30 June 1957

No.	Formula	Compound	Type [a]	Boiling point at 1 atm [b]	Purity of the best sample isolated [c]	Estimated amount in the crude petroleum [d]
				°C	Mol %	Volume %
1	CH_4	Methane	Normal paraffin	−161·49	[e]	[e]
2	C_2H_6	Ethane	Normal paraffin	− 88·63	[e]	[e]
3	C_3H_8	Propane	Normal paraffin	− 42·07	[e]	[e]
4	C_4H_{10}	*Iso*Butane	Branched paraffin	− 11·73	[e]	[e]
5	C_4H_{10}	*n*-Butane	Normal paraffin	− 0·50	[e]	[e]
6	C_5H_{12}	2-Methylbutane	Branched paraffin	27·85	[e]	[e]
7	C_5H_{12}	*n*-Pentane	Normal paraffin	36·07	[e]	[e]
8	C_5H_{10}	*cyclo*Pentane	*cyclo*Pentane	49·26	[e]	0·05
9	C_6H_{14}	2,2-Dimethylbutane	Branched paraffin	49·74	[e]	0·04
10	C_6H_{14}	2,3-Dimethylbutane	Branched paraffin	57·99	97	0·08
11	C_6H_{14}	2-Methylpentane	Branched paraffin	60·27	99·97	0·37
12	C_6H_{14}	3-Methylpentane	Branched paraffin	63·28	99·9	0·35
13	C_6H_{14}	*n*-Hexane	Normal paraffin	68·74	99·9	1·80
14	C_6H_{12}	Methyl*cyclo*pentane	*cyclo*Pentane	71·81	98·7	0·87
15	C_7H_{16}	2,2-Dimethylpentane	Branched paraffin	79·20	97	0·02
16	C_6H_6	Benzene	Benzene	80·10	99·6	0·15
17	C_7H_{16}	2,4-Dimethylpentane	Branched paraffin	80·50	[e]	0·08
18	C_6H_{12}	*cyclo*Hexane	*cyclo*Hexane	80·74	99·9	0·71
19	C_7H_{14}	1,1-Dimethyl*cyclo*pentane	*cyclo*Pentane	87·85	98	0·16
20	C_7H_{16}	2,3-Dimethylpentane	Branched paraffin	89·78	58 [f]	0·15 [g]
21	C_7H_{16}	2-Methylhexane	Branched paraffin	90·05	97	0·73 [g]
22	C_7H_{14}	1,*cis*-3-Dimethyl*cyclo*pentane [h]	*cyclo*Pentane	90·77	85	0·87 [g]
23	C_7H_{14}	1,*trans*-3-Dimethyl*cyclo*pentane [i]	*cyclo*Pentane	91·72	51 [f]	0·21 [g]
24	C_7H_{16}	3-Methylhexane	Branched paraffin	91·85	93	0·51
25	C_7H_{14}	1,*trans*-2-Dimethyl*cyclo*pentane	*cyclo*Pentane	91·87	93	0·48 [g]
26	C_7H_{16}	3-Ethylpentane	Branched paraffin	93·48	98·7 [f]	0·06
27	C_7H_{16}	*n*-Heptane	Normal paraffin	98·43	99·9	2·30
28	C_7H_{14}	Methyl*cyclo*hexane	*cyclo*Hexane	100·93	99·8	1·60
29	C_7H_{14}	Ethyl*cyclo*pentane	*cyclo*Pentane	103·47	98	0·16
30	C_8H_{16}	1,1,3-Trimethyl*cyclo*pentane	*cyclo*Pentane	104·89	98·1	0·30
31	C_8H_{18}	2,2-Dimethylhexane	Branched paraffin	106·84	50 [f]	0·01
32	C_8H_{18}	2,5-Dimethylhexane	Branched paraffin	109·10	55 [f]	0·06 [f]
33	C_8H_{16}	1,*trans*-2,*cis*-4-Trimethyl*cyclo*pentane	*cyclo*Pentane	109·29	84 [f]	0·22
34	C_8H_{18}	2,4-Dimethylhexane	Branched paraffin	109·43	41 [f]	0·06
35	C_8H_{18}	2,2,3-Trimethylpentane	Branched paraffin	109·84	1	0·004
36	C_8H_{16}	1,*trans*-2,*cis*-3-Trimethyl*cyclo*pentane	*cyclo*Pentane	110·20	98·6	0·26
37	C_7H_8	Toluene	Benzene	110·62	98	0·51
38	C_8H_{18}	3,3-Dimethylhexane	Branched paraffin	111·97	86 [f]	0·03
39	C_8H_{18}	2,3,4-Trimethylpentane	Branched paraffin	113·47	17 [f]	0·005 [f]
40	C_8H_{16}	1,1,2-Trimethyl*cyclo*pentane	*cyclo*Pentane	113·73	98	0·06
41	C_8H_{18}	2,3,3-Trimethylpentane	Branched paraffin	114·76	10 [f]	0·006
42	C_8H_{18}	2,3-Dimethylhexane	Branched paraffin	115·61	65 [f]	0·07 [f]
43	C_8H_{18}	2-Methyl-3-ethylpentane	Branched paraffin	115·65 [h]	51 [g]	0·06 [f]
44	C_8H_{16}	1,*cis*-2,*trans*-4-Trimethyl*cyclo*pentane	*cyclo*Pentane	116·73	84 [g]	0·01 [g]
45	C_8H_{16}	1,*cis*-2,*trans*-3-Trimethyl*cyclo*pentane	*cyclo*Pentane	117·50	90 [g]	0·07 [g]
46	C_8H_{18}	2-Methylheptane	Branched paraffin	117·65	90	0·90 [g]
47	C_8H_{18}	4-Methylheptane	Branched paraffin	117·71	34 [g]	0·20 [g]
48	C_8H_{18}	3,4-Dimethylhexane	Branched paraffin	117·72	40 [g]	0·13 [g]
49	C_8H_{18}	3-Methyl-3-ethylpentane	Branched paraffin	118·26	6 [g]	0·02 [g]
50	C_8H_{18}	3-Ethylhexane	Branched paraffin	118·53	43 [g]	0·09 [g]
51	C_7H_{14}	*cyclo*Heptane	*cyclo*Heptane	118·79	90	0·01 [g]
52	C_8H_{18}	3-Methylheptane	Branched paraffin	118·92	98 [g]	0·30 [g]
53	C_8H_{16}	1,*trans*-4-Dimethyl*cyclo*hexane	*cyclo*Hexane	119·35	75 [g]	0·25 [g]
54	C_8H_{16}	1,1-Dimethyl*cyclo*hexane	*cyclo*Hexane	119·54	84 [g]	0·06 [g]
55	C_8H_{16}	1,*cis*-3-Dimethyl*cyclo*hexane	*cyclo*Hexane	120·09	84 [g]	0·63 [g]
56	C_8H_{16}	1-Methyl-*trans*-3-ethyl*cyclo*pentane	*cyclo*Pentane	120·80	57 [g]	0·12 [g]
57	C_8H_{16}	1-Methyl-*cis*-3-ethyl*cyclo*pentane	*cyclo*Pentane	121·40 }	74 [g]	0·14 [g]
58	C_8H_{16}	1-Methyl-*trans*-2-ethyl*cyclo*pentane	*cyclo*Pentane	121·20 }		
59	C_8H_{16}	1-Methyl-1-ethyl*cyclo*pentane	*cyclo*Pentane	121·52	65 [g]	0·03 [g]
60	C_9H_{18}	1,1,*cis*-3,*trans*-4-Tetramethyl*cyclo*-pentane	*cyclo*Pentane	121·60	83 [g]	0·04 [g]
61	C_8H_{14}	1,*trans*-2-Dimethyl*cyclo*hexane	*cyclo*Hexane	123·42	98 [g]	0·31 [g]
62	C_9H_{20}	2,2,5-Trimethylhexane	Branched paraffin	124·08	11 [g]	0·002 [g]
63	C_8H_{16}	1,*cis*-4-Dimethyl*cyclo*hexane	*cyclo*Hexane	124·32	76 [g]	0·09 [g]
64	C_8H_{16}	1,*trans*-3-Dimethyl*cyclo*hexane	*cyclo*Hexane	124·45	49 [g]	0·07 [g]
65	C_8H_{14}	Methylbi*cyclo*-[2,2,1]-heptane [j]	Bi*cyclo*paraffin	124·50	[e]	0·001
66	C_8H_{18}	*n*-Octane	Normal paraffin	125·66	99·2	1·90

TABLE VII.—*continued*

No.	Formula	Compound	Type [a]	Boiling point at 1 atm [b]	Purity of the best sample isolated [c]	Estimated amount in the crude petroleum [d]
				°C	Mole %	Volume %
67	C_8H_{16}	*iso*Propyl*cyclo*pentane	*cyclo*Pentane	126·42	15 [g]	0·01 [g]
68	C_9H_{18}	1,*trans*-2,*cis*-3,*trans*-4-Tetramethyl*cyclo*-pentane	*cyclo*Pentane	127·40	90	0·11
69	C_8H_{16}	1-Methyl-*cis*-2-ethyl*cyclo*pentane	*cyclo*Pentane	128·05	52 [g]	0·04 [g]
70	C_8H_{16}	1,*cis*-2-Dimethyl*cyclo*hexane	*cyclo*Hexane	129·73	45 [g]	0·06 [g]
71	C_8H_{16}	*n*-Propyl*cyclo*pentane	*cyclo*Pentane	130·95	49 [g]	0·06 [g]
72	C_9H_{20}	2,3,5-Trimethylhexane	Branched paraffin	131·34	16 [g]	0·03 [g]
73	C_8H_{16}	Ethyl*cyclo*hexane	*cyclo*Hexane	131·78	94	0·37 [g]
74	C_9H_{20}	2,6-Dimethylheptane	Branched paraffin	135·21	98·6	0·05
75	C_8H_{10}	Ethylbenzene	Benzene	136·19	96	0·19
76	C_8H_{14}	*cis*-Bi*cyclo*-[3,3,0]-octane	Bi*cyclo*paraffin	136·50	95	0·06
77	C_8H_{14}	Bi*cyclo*-[3,2,1]-octane	Bi*cyclo*paraffin	138·00	>90	0·008
78	C_9H_{18}	1,1,3-Trimethyl*cyclo*hexane	*cyclo*Hexane	136·63	99·9	0·2
79	C_8H_{10}	*p*-Xylene	Benzene	138·35	99·8	0·10
80	C_8H_{10}	*m*-Xylene	Benzene	139·10	99·9	0·51
81	C_9H_{20}	2,3-Dimethylheptane	Branched paraffin	140·50	60	0·05
82	C_9H_{18}	1,*trans*-2,*trans*-4-Trimethyl*cyclo*hexane	*cyclo*Hexane	141·20	95	0·2
83	C_9H_{20}	4-Methyloctane	Branched paraffin	142·48	80	0·1
84	C_9H_{20}	2-Methyloctane	Branched paraffin	143·26	99·9	0·4
85	C_9H_{20}	3-Methyloctane	Branched paraffin	144·18	95	0·1
86	C_8H_{10}	*o*-Xylene	Benzene	144·41	99·7	0·27
87	C_9H_{18}	1,*trans*-2,*cis*-4-Trimethyl*cyclo*hexane	*cyclo*Hexane	145·60	99	*
88	C_9H_{16}	Bi*cyclo*paraffin [e]	Bi*cyclo*paraffin	146·70	99	*
89	C_9H_{20}	*n*-Nonane	Normal paraffin	150·80	99·94	1·8
90	C_9H_{12}	*iso*Propylbenzene	Benzene	152·39	99·8	0·07 [i]
91	C_9H_{12}	*n*-Propylbenzene	Benzene	159·22	98	0·09 [i]
92	C_9H_{12}	1-Methyl-3-ethylbenzene	Benzene	161·30	99 [f]	0·17 [i]
93	C_9H_{12}	1-Methyl-4-ethylbenzene	Benzene	161·99	94 [f]	0·06 [i]
94	C_9H_{12}	1,3,5-Trimethylbenzene	Benzene	164·72	99·9	0·12 [i]
95	C_9H_{12}	1-Methyl-2-ethylbenzene	Benzene	165·15	89 [g]	0·09 [i]
96	$C_{10}H_{22}$	4-Methylnonane	Branched paraffin	165·70	96	0·1
97	$C_{10}H_{22}$	2-Methylnonane	Branched paraffin	166·80	99·9	0·3
98	$C_{10}H_{22}$	3-Methylnonane	Branched paraffin	167·80	98	0·1
99	$C_{10}H_{14}$	*tert.*-Butylbenzene	Benzene	169·12	*	0·01 [i]
100	C_9H_{12}	1,2,4-Trimethylbenzene	Benzene	169·35	99·7	0·51 [i]
101	$C_{10}H_{14}$	*iso*Butylbenzene	Benzene	172·76	28 [f]	0·008 [f]
102	$C_{10}H_{14}$	*sec*-Butylbenzene	Benzene	173·30	68 [f]	0·017 [f]
103	$C_{10}H_{22}$	*n*-Decane	Normal paraffin	174·12	99·9	1·8
104	$C_{10}H_{14}$	1-Methyl-3-*iso*propylbenzene	Benzene	175·14	92 [g]	0·08 [f]
105	C_9H_{12}	1,2,3-Trimethylbenzene	Benzene	176·08	99·8	0·19 [f]
106	$C_{10}H_{14}$	1-Methyl-4-*iso*propylbenzene	Benzene	177·10	96	0·04 [f]
107	C_9H_{10}	Indan	Aromatic *cyclo*paraffin	177·80	41 [f]	0·003
108	$C_{10}H_{14}$	1-Methyl-2-*iso*propylbenzene	Benzene	178·15	32 [f]	0·009 [f]
109	$C_{10}H_{14}$	1,3-Diethylbenzene	Benzene	181·10	61 [g]	*
110	$C_{10}H_{14}$	1-Methyl-3-propylbenzene	Benzene	181·80	60 [g]	*
111	$C_{10}H_{14}$	*n*-Butylbenzene	Benzene	183·27	51 [g]	*
112	$C_{10}H_{14}$	1-Methyl-4-propylbenzene	Benzene	183·30	43 [g]	*
113	$C_{10}H_{14}$	1,2-Diethylbenzene	Benzene	183·42	64 [g]	*
114	$C_{10}H_{14}$	1,3-Dimethyl-5-ethylbenzene	Benzene	183·58	87 [g]	*
115	$C_{10}H_{14}$	1,4-Diethylbenzene	Benzene	183·78	*	*
116	$C_{10}H_{14}$	1-Methyl-2-propylbenzene	Benzene	184·80	87	*
117	$C_{10}H_{14}$	1,4-Dimethyl-2-ethylbenzene	Benzene	186·83	75	*
118	$C_{10}H_{18}$	*trans*-Decahydronaphthalene	Bi*cyclo*paraffin	187·25	*	*
119	$C_{10}H_{14}$	1,3-Dimethyl-4-ethylbenzene	Benzene	188·20	58	*
120	$C_{10}H_{14}$	1,2-Dimethyl-4-ethylbenzene	Benzene	189·48	90	*
121	$C_{10}H_{14}$	1,3-Dimethyl-2-ethylbenzene	Benzene	190·01	60	*
122	$C_{10}H_{12}$	1-Methylindan	Aromatic *cyclo*paraffin	190·60	} 34 [g]	
123	$C_{10}H_{12}$	2-Methylindan	Aromatic *cyclo*paraffin	191·40		
124	$C_{10}H_{14}$	1,2-Dimethyl-3-ethylbenzene	Benzene	193·91	84	*
125	$C_{11}H_{24}$	*n*-Undecane	Normal paraffin	195·89	99·97	1·6
126	$C_{10}H_{14}$	1,2,4,5-Tetramethylbenzene	Benzene	196·80	97·2	*
127	$C_{10}H_{14}$	1,2,3,5-Tetramethylbenzene	Benzene	198·00	95·4	*
128	$C_{11}H_{20}$	Di*cyclo*paraffin	Di*cyclo*paraffin	202·50	*	*
129	$C_{11}H_{16}$	1-Methyl-3-*n*-butylbenzene	Benzene	204·10	98	0·06
130	$C_{10}H_{14}$	1,2,3,4-Tetramethylbenzene	Benzene	205·04	99·9	0·2
131	$C_{10}H_{12}$	4-Methylindan	Aromatic *cyclo*paraffin	205·50	68 [g]	*
132	$C_{11}H_{16}$	1,3-Dimethyl-4-*n*-propylbenzene [j]	Benzene	206·60	96	0·03
133	$C_{10}H_{12}$	1,2,3,4-Tetrahydronaphthalene	Aromatic *cyclo*paraffin	207·57	98·5	0·03
134	$C_{11}H_{16}$	1,2-Dimethyl-4-*n*-propylbenzene [j]	Benzene	208·50	99	0·03

TABLE VII—*continued*

No.	Formula	Compound	Type [a]	Boiling point at 1 atm [b]	Purity of the best sample isolated [c]	Estimated amount in the crude petroleum [d]
				°C	Mol %	Volume %
135	$C_{11}H_{16}$	Trimethylethylbenzene	Benzene	212·30	97	0·04
136	$C_{12}H_{26}$	*n*-Dodecane	Normal paraffin	216·28	99·9	1·4
137	$C_{10}H_8$	Naphthalene	Dinuclear aromatic	217·96	99·9	0·06
138	$C_{11}H_{14}$	2-Methyl-[1,2,3,4-tetrahydronaphthalene]	Aromatic *cyclo*paraffin	220·70	97	0·04
139	$C_{11}H_{14}$	6-Methyl-[1,2,3,4-tetrahydronaphthalene]	Aromatic *cyclo*paraffin	229·03	99·5	0·09
140	$C_{11}H_{14}$	5-Methyl-[1,2,3,4-tetrahydronaphthalene]	Aromatic *cyclo*paraffin	234·35	99·7	0·08
141	$C_{13}H_{28}$	*n*-Tridecane	Normal paraffin	235·43	98	1·2
142	$C_{11}H_{10}$	2-Methylnaphthalene	Dinuclear aromatic	241·05	99·9	0·2
143	$C_{11}H_{10}$	1-Methylnaphthalene	Dinuclear aromatic	244·64	99·7	0·1
144	$C_{14}H_{30}$	*n*-Tetradecane	Normal paraffin	253·52	98·5 [m]	1·0
145	$C_{12}H_{10}$	Biphenyl	Dinuclear aromatic	255·20	[e]	[e]
146	$C_{12}H_{12}$	2,6-Dimethylnaphthalene	Dinuclear aromatic	262·00	[e]	[e]
147	$C_{12}H_{12}$	Dimethylnaphthalene [j]	Dinuclear aromatic	268·00	[e]	[e]
148	$C_{15}H_{32}$	*n*-Pentadecane	Normal paraffin	270·61	98·5 [n]	0·8
149	$C_{12}H_{14}$	Trimethylnaphthalene [j]	Dinuclear aromatic	288·00	[e]	[e]
150	$C_{16}H_{34}$	*n*-Hexadecane	Normal paraffin	286·79	98 [m]	0·7
151	$C_{17}H_{36}$	*n*-Heptadecane	Normal paraffin	301·82	97 [m]	0·6
152	$C_{14}H_{10}$	Dinuclear aromatic [k]	Dinuclear aromatic	312·00	[e]	[e]
153	$C_{18}H_{38}$	*n*-Octadecane	Normal paraffin	316·12	[e]	0·50
154	$C_{19}H_{40}$	*n*-Nonadecane	Normal paraffin	329·70	[e]	0·43
155	$C_{20}H_{42}$	*n*-Eicosane	Normal paraffin	342·70	[e]	0·37
156	$C_{21}H_{44}$	*n*-Heneicosane	Normal paraffin	355·10	[e]	0·32
157	$C_{22}H_{46}$	*n*-Docosane	Normal paraffin	367·00	[e]	0·28
158	$C_{23}H_{48}$	*n*-Tricosane	Normal paraffin	378·30	[e]	0·24
159	$C_{24}H_{50}$	*n*-Tetracosane	Normal paraffin	389·20	[e]	0·21

[a] The compounds are classified according to the following types: normal paraffin; branched paraffin; *cyclo*pentane (and its alkyl derivatives); *cyclo*hexane (and its alkyl derivatives); benzene (and its alkyl derivatives); bi*cyclo*paraffin (having two *cyclo*paraffin rings joined through two carbon atoms); di*cyclo*paraffin (having two *cyclo*paraffin rings joined through one carbon atom, or of unknown connexion); dinuclear aromatic; aromatic *cyclo*paraffin (mixed type).

[b] This is the value for the pure compound, as taken from the tables and files of the API Research Project 44, and is not necessarily the temperature at which the compound appears in the distillation of the appropriate fraction of petroleum.

[c] Where the amount of the best sample isolated was sufficient, and the sample was crystallizable, the purity has been calculated from the value of the freezing point previously reported and the present best values of the freezing point for zero impurity and cryoscopic constants from the API Research Projects 44 and 6. Where not evaluated cryoscopically, the purity has been evaluated from spectrographic measurements or it has been estimated.

[d] The values for the amount in the crude petroleum are rounded estimates subject to revision as new data become available from the work in progress.

[e] Not determined.

[f] Determined spectrographically from measurements made in the Socony Mobil Laboratories, Paulsboro, N.J.

[g] Determined spectrographically from measurements made in the laboratories of the Humble Oil and Refining Company, Houston, Texas.

[h] This isomer, formerly labelled "*trans*," has the following properties: boiling point at 1 atm, 90·77° C; refractive index n_D at 25° C, 1·4063; density at 25° C, 0·7402 g/ml.

[i] This isomer, formerly labelled "*cis*," has the following properties: boiling point at 1 atm, 91·72° C; refractive index, n_D at 25° C, 1·4081; density at 25° C, 0·7444 g/ml.

[j] Tentative; identification not complete.

[k] Identity not yet established.

[l] Determined spectrographically from measurements made in the following laboratories: Humble Oil and Refining Company, Baytown, Texas; Socony Mobil Laboratories, Paulsboro, N.J.; Esso Research and Engineering Company, Linden, N.J.; Sun Oil Company, Norwood, Pa.

[m] Purification of these samples was not carried to completion because, for purposes of identification, much purer samples were available from other sources.

Table X shows the relative amounts of benzene, toluene, and the four C_8 alkyl benzenes (ethylbenzene, *o*-xylene, *m*-xylene, and *p*-xylene) in the seven representative gasolines. Table XI gives the same information for *cyclo*hexane and methyl*cyclo*hexane, and Table XII similar information for the two methylpentanes and the two dimethylbutanes.

These results mean that the information and data obtained at great cost through the exhaustive fractionation of the Project's one representative petroleum can be readily translated to other petroleums by making some relatively simple observations on the other petroleums.

It is important to emphasize that this work has

TABLE VIII

Gasoline Fractions from Seven Representative Petroleums

	Source field	Supplier	Type	Content of sulphur, by by weight	Content of aromatics, % by volume
A	Ponca, Oklahoma	Continental Oil Co.	Intermediate	0·017	9·8
B	East Texas	Standard Oil Development Co.	Intermediate	0·033	10·4
C	Bradford, Pennsylvania	Quaker State Oil Refining Co.	High in paraffins	0·012	8·3
D	Greendale-Kawkawlin, Michigan	Pure Oil Co.	High in normal paraffins	0·014	7·2
E	Winkler, Texas	Standard Oil Co. (Indiana)	High in branched paraffins	0·159	4·9
F	Midway, California	Standard Oil Co. of California	High in alkyl *cyclo*pentanes and alkyl *cyclo*hexanes	0·045	8·0
G	Conroe, Texas	Humble Oil and Refining Co.	High in aromatics	0·002	27·6

TABLE IX

Relative Amounts of the Principal Five Classes of Hydrocarbons in the Seven Representative Gasolines

Class of hydrocarbons	Relative amount of the 40° to 102° C fraction						
	Ponca, Oklahoma	East Texas	Bradford, Pennsylvania	Greendale-Kawkawlin, Michigan	Winkler, Texas	Midway, California	Conroe, Texas
Normal paraffins	35·3	24·6	34·1	62·2	9·5	9·9	17·6
Branched paraffins	20·2	27·1	32·0	13·0	61·4	21·4	19·6
Alkyl *cyclo*pentanes	23·1	25·9	13·4	7·8	20·4	40·7	16·6
Alkyl *cyclo*hexanes	20·2	21·9	20·0	15·5	8·2	27·4	42·6
Alkyl benzenes	1·2	0·5	0·5	1·5	0·5	0·6	3·6
Total	100·0	100·0	100·0	100·0	100·0	100·0	100·0

TABLE X

Relative Amounts of the C_6, C_7, and C_8 Aromatic Hydrocarbons in Seven Representative Petroleums

Components	Petroleum							Range of values	Average value
	A	B	C	D	E	F	G		
Benzene	9	4	4	13	10	5	6	4–13	7
Toluene	30	29	31	37	20	30	38	20–38	31
C_8 Alkyl benzenes	61	67	65	50	70	65	56	50–70	62
Total	100	100	100	100	100	100	100	—	100
Total actual amount in the gasoline fraction, %	5·4	5·9	4·9	4·8	1·3	4·3	19·5		

TABLE XI

Relative Amounts of cyclo*Hexane and Methyl*cyclo*hexane in Seven Representative Petroleums*

Components	Petroleum							Range of values	Average value
	A	B	C	D	E	F	G		
*cyclo*Hexane	30	21	24	33	31	29	30	21–33	28
Methyl*cyclo*hexane	70	79	76	67	69	71	70	67–79	72
Total	100	100	100	100	100	100	100	—	100
Total actual amount in the gasoline fraction, %	6·9	8·4	7·3	6·1	2·1	8·4	13·7		

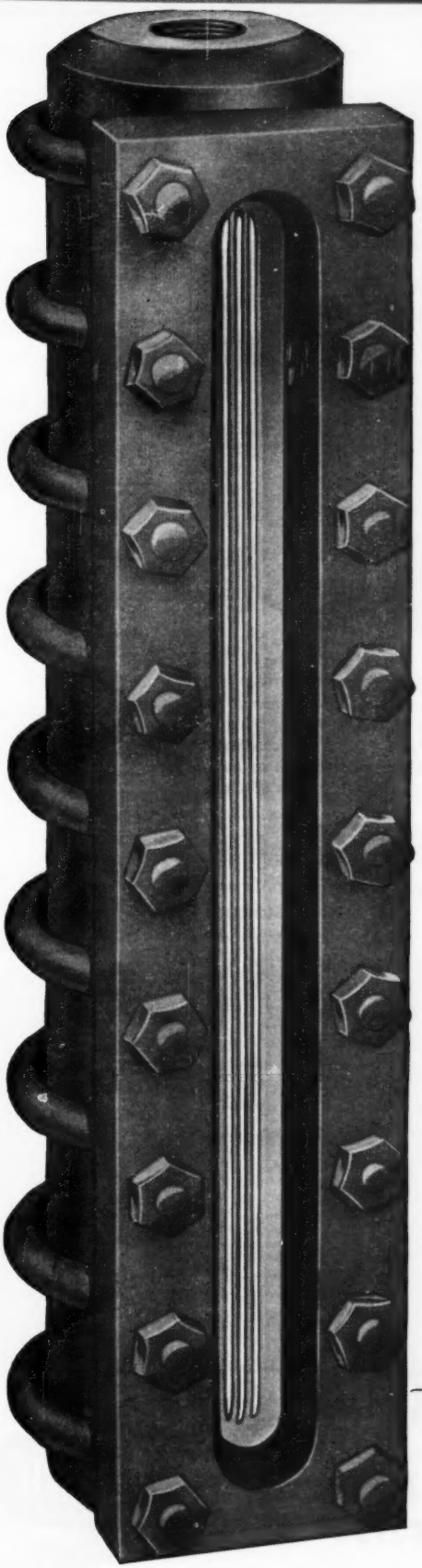
TABLE XII

Relative Amounts of the Two Methylpentanes and the Two Dimethylbutanes in Seven Representative Petroleums

Components	Petroleum							Range of values	Average value
	A	B	C	D	E	F	G		
Dimethylbutanes	14	13	10	14	12	16	16	10–16	14
Methylpentanes	86	87	90	86	88	84	84	84–90	86
Total	100	100	100	100	100	100	100	—	100
Total actual amount in the gasoline fraction, %	2·6	4·8	6·0	2·6	6·6	3·4	3·1		

involved a large number of people working over many years. These have included undergraduate students, graduate students, laboratory technicians, and professional chemists with bachelor's, master's, and doctor's degrees.

The results reported have required nearly 500 man-years of work, spread over a period of thirty years. Up to the present, the API has invested nearly one and a half million dollars in this work and deserves great credit for making the results available promptly to science and industry in the free world without preference.

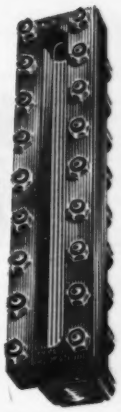


Klinger

LIQUID LEVEL GAUGES

TYPE "UL" LEVEL GAUGE
A general purpose level indicator suitable for moderate pressures.
400 lb. rating : 540 p.s.i. at 660°F.
800 p.s.i. at 100°F.

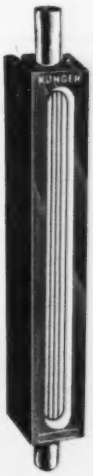
TYPE "U" LEVEL GAUGE
A general purpose level indicator similar to the "UL" type, but designed for higher working pressures and temperatures. Widely used in the oil industry as it conforms to American practice.
600 lb. rating : 820 p.s.i. at 660°F.
1200 p.s.i. at 100°F.



TYPE "O" LARGE CHAMBER REFLEX GAUGE

Specially designed for use with liquids which boil at ambient temperatures, for thick viscous liquids and suspensions.
600 lb. rating : 820 p.s.i. at 660°F.
1200 p.s.i. at 100°F.

TYPE "J" & "JA" DOUBLE PLATE, thru-vision LEVEL GAUGE
This type of level indicator is extensively used by the oil industry in all types of service. Mica plates can be fitted to protect the glasses from the action of the contained fluid.
600 lb. rating : 820 p.s.i. at 660°F.
1200 p.s.i. at 100°F.



TYPE "K" LEVEL GAUGE
A general purpose level indicator similar to the "U" type indicator, but lighter and narrower. It is sometimes fitted with a plate glass for use with mercury.
600 lb. rating : 820 p.s.i. at 660°F.
1200 p.s.i. at 100°F.

Write for full details of the complete range of Klinger Liquid Level Gauges.

Richard Klinger Limited

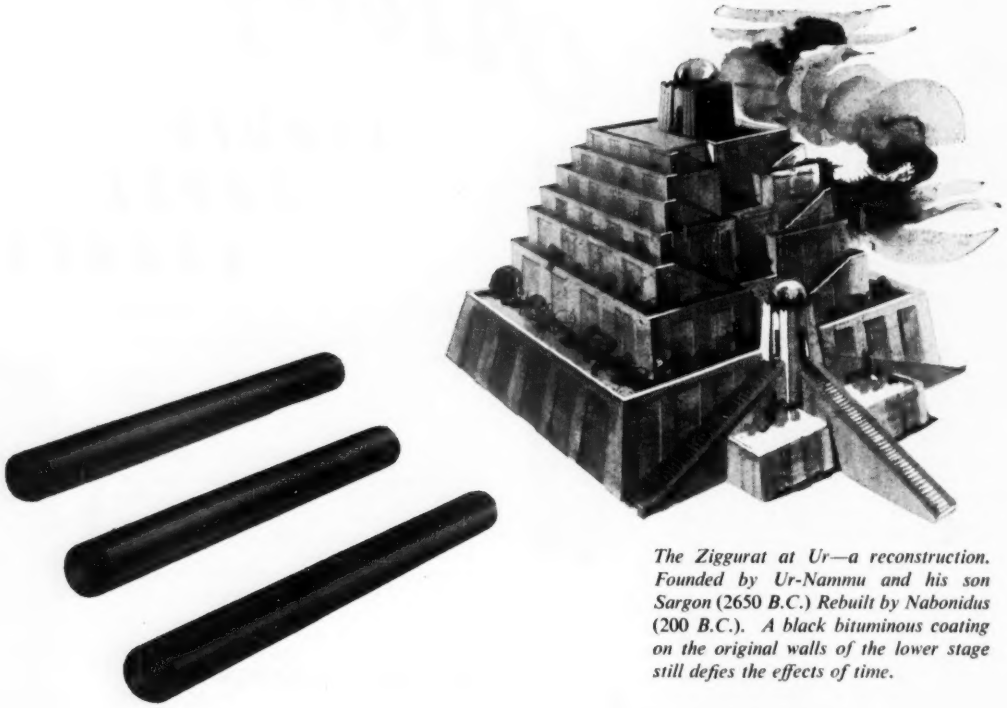
KLINGERIT WORKS · SIDCUP · KENT · ENGLAND

Foots Cray 7777

G38/58/5G.

a

RESTORATION



The Ziggurat at Ur—a reconstruction. Founded by Ur-Nammu and his son Sargon (2650 B.C.) Rebuilt by Nabonidus (200 B.C.). A black bituminous coating on the original walls of the lower stage still defies the effects of time.

The reconstruction of buried cities, palaces and temples, of fragmented pots and broken statuary holds a consuming interest and fascination. The rate of destruction by the forces of nature varies considerably from region to region. In the Middle East where monuments of past civilizations have been preserved for centuries, it is ironical that modern works of steel should be subject to rapid deterioration. Preservation and protection present problems and demand high standards, but it is easier to preserve and maintain than to reconstruct.

In pipeline engineering, where great responsibility is vested in coatings chosen to protect the line, " Bitumastic " products are held in high esteem. Throughout America, Canada and in the tough proving-ground of the Middle-East these materials have demonstrated, over the years, their efficiency and reliability.

Many major Oil Companies use " Bitumastic " products exclusively for pipeline protection. For a list of these and other information send today for a copy of our Pipeline Data Booklet.

BITUMASTIC

SPECIALISTS IN ANTI-CORROSIVE COATINGS
SPECIALISTS IN PIPELINE PROTECTION

"BITUMASTIC"
REGISTERED TRADE MARK

H135 WAILES DOVE BITUMASTIC LTD · HEBBURN · CO. DURHAM

BAKER
IS *ALWAYS* "FIRST"

ALWAYS "First" in successful results, which means just ONE thing—securing a permanent, leak-proof shut-off with the primary cement job. Nothing seals like the Buoyant Baker BALL Valve which seats instantly on the rubber seal when pressure is reversed. And only "drillable" materials are used in Baker Cementing Shoes and Collars.

"First" and ALWAYS Best with new and improved products, such as Baker Differential FILL-UP Equipment and Baker FLEXIFLOW Fill-Up Equipment, both of which permit the casing to *fill automatically from the bottom* while it is being run in the well. You save time in running casing; minimize the "ram effect" which breaks down potential lost circulation zones; eliminate the hazards and discomfort of surface filling the casing.

ALWAYS "First" Choice because you (and thousands of other operators) recognize that Baker products and methods provide dependable performance.

This is the time tested Baker Cement Float Collar (Product No. 101 M&F) usually positioned just above the shoe joint to provide a "stop" for the cementing plug. Used in combination with any type of Baker Cement Float Shoe, Guide Shoe, or the "Whirler" Shoe to meet the customer's need.

This is the Baker DIFFERENTIAL Fill-Up Shoe (Product No. 1081) which permits the casing to fill automatically from the bottom while it is being run. A variable valve opens to relieve destructive high pressure surges, and closes to regulate casing fill. Ask for Catalog Supplement No. 301, describing DIFFERENTIAL Fill-Up Equipment.

This is the new Baker FLEXIFLOW Fill-Up Shoe (Product No. 160). Permits casing to fill from the bottom through a hole in a flexible diaphragm that opens up to relieve dangerous high pressure surges, and closes down to control casing fill. Cuts casing running time by as much as one-third. Ask for Catalog Supplement No. 325.

This is the Baker Cement GUIDE Shoe usually run in combination with Baker FILL-UP Collars or Float Collars when one back pressure valve is considered sufficient. Safely guides casing to bottom. Specify Product No. 102.

BAKER OIL TOOLS, INC.

HOUSTON • LOS ANGELES • NEW YORK

BAKER will ALWAYS be "FIRST"

with better tools for successful cementing.

Atmospheric and Vacuum Distillation Units

Combined Distillation, Cracking, Reforming and Vapour Phase Treating Units

Pressure Distillate Re-run Units

Gasoline Recovery and Stabilization Units

Fractionating Columns and Tube Stills

Wax Refining, Sweating and Moulding

A. F. CRAIG & COMPANY LIMITED

CALEDONIA ENGINEERING WORKS • **PAISLEY** • **SCOTLAND**

LONDON OFFICE: 727 SALISBURY HOUSE · LONDON WALL · E.C.2 · PHONE **NAT**IONAL **3964**

45 cubic metre Pressure Vessel

made for I.C.I. Billingham Division. Length 30 feet. Diameter 10 feet. Fabricated from Kynal M.35/1. Aluminium Alloy ⅜" thick. One end dished and a rolled body cone and skirt. Argon Arc welded throughout.

MARSTON EXCELSIOR *in the Service of Industry*

Marston's have unrivalled experience in the fabrication of light alloys—of all shapes and sizes. Their products have earned a reputation for efficiency and reliability that is world-wide.

- ★ *Light Alloy Fabrication*
- ★ *Specialised Engineering Assemblies*
- ★ *Laminated Plastic Components*
- ★ *Flexible Tanks*
- ★ *Radiators and Heat Exchangers*

Tubular Heat Exchangers

5 pass cross/contra type made for I.C.I. Billingham Division. Length 18½ feet. Diam. 23½" inside. Header tanks are Aluminium Castings of BS.1490 LM.20 alloy ⅜" thick. Body rolled and welded from PA.19 Aluminium Alloy Plate ¼" thick.
Tested to 75 p.s.i.

Oil Tank

of 2500 gallon capacity, made for I.C.I. Paints Division. Length 14 feet. Diameter 7 feet. Fabricated from Kynal P3. Aluminium alloy ⅜" thick with dished ends and a rolled plate body. Argon Arc welded throughout. Tested to withstand an 18 foot head of water.

MARSTON EXCELSIOR LIMITED

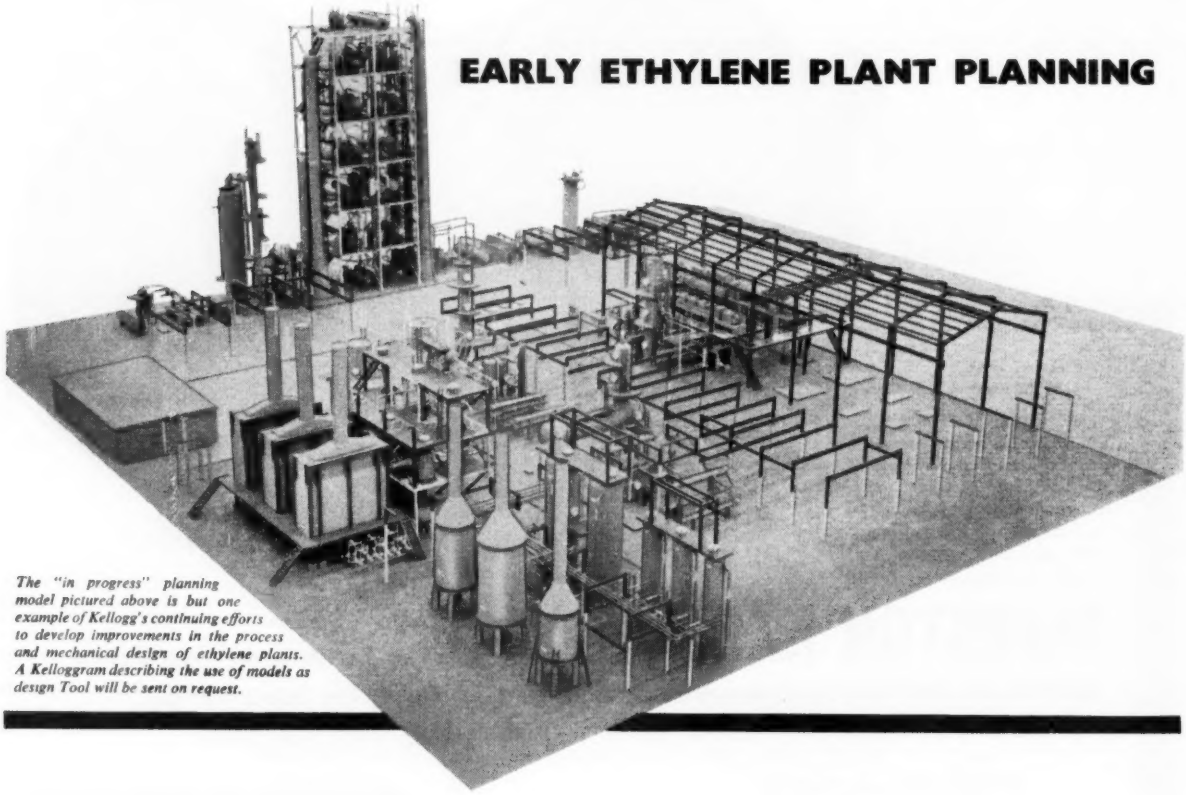
(A subsidiary company of Imperial Chemical Industries Ltd.)

FORDHOUSES, WOLVERHAMPTON. Tel: Fordhouses 3361

ICI

MAR232

EARLY ETHYLENE PLANT PLANNING



The "in progress" planning model pictured above is but one example of Kellogg's continuing efforts to develop improvements in the process and mechanical design of ethylene plants. A Kelloggram describing the use of models as design Tool will be sent on request.

Your best plan for undertaking a new ethylene plant is to utilize the ethylene experience of the Kellogg organisation. This experience includes the process engineering and design engineering of seven ethylene plants for the leading petrochemical firms in England, France, Germany and Italy. The Kellogg ethylene experience also includes the engineering of the largest and most complex ethylene gas recovery and purification plants for major petroleum refiners in the U.S.A.

The Kellogg developed process for the direct production of ethylene by steam pyrolosis of petroleum fractions is an established technical and commercial success. This process permits considerable flexibility in feed stocks, ranging from ethane through propane and naphtha, to gas oils. The ratios of light olefines yields can be varied by changing the operating conditions of the process. An ethylene of 99.9% purity can be produced.

Kellogg International Corporation welcome the opportunity to explain how the Kellogg ethylene experience can be utilised by firms interested in producing or recovering ethylene and other olefines.

Kellogg International Corporation

KELLOGG HOUSE · 7-8 CHANDOS STREET · CAVENDISH SQUARE · LONDON · W.1

SOCIETE KELLOGG · PARIS
THE CANADIAN KELLOGG COMPANY LTD · TORONTO
KELLOGG PAN AMERICAN CORPORATION · NEW YORK
COMPANHIA KELLOGG BRASILEIRA · RIO DE JANEIRO
COMPANIA KELLOGG DE VENEZUELA · CARACAS

Subsidiaries of
THE M. W. KELLOGG COMPANY
NEW YORK

PETROLEUM REFINERIES
PETROCHEMICAL PLANTS

GAS STORAGE without operating costs

The WIGGINS dry seal type of gasholder is the only gasholder with an absolutely dry frictionless seal—it does not use water, tar or grease. Its design ensures that weather worries, operating costs and maintenance problems are virtually non-existent. More than fifty WIGGINS gasholders have been manufactured by Ashmore, Benson, Pease & Co since the introduction of this design to Great Britain in 1951. Capacities ranging from 50 cubic feet to 500,000 cubic feet have been erected and larger sizes have been designed.

Write for particulars

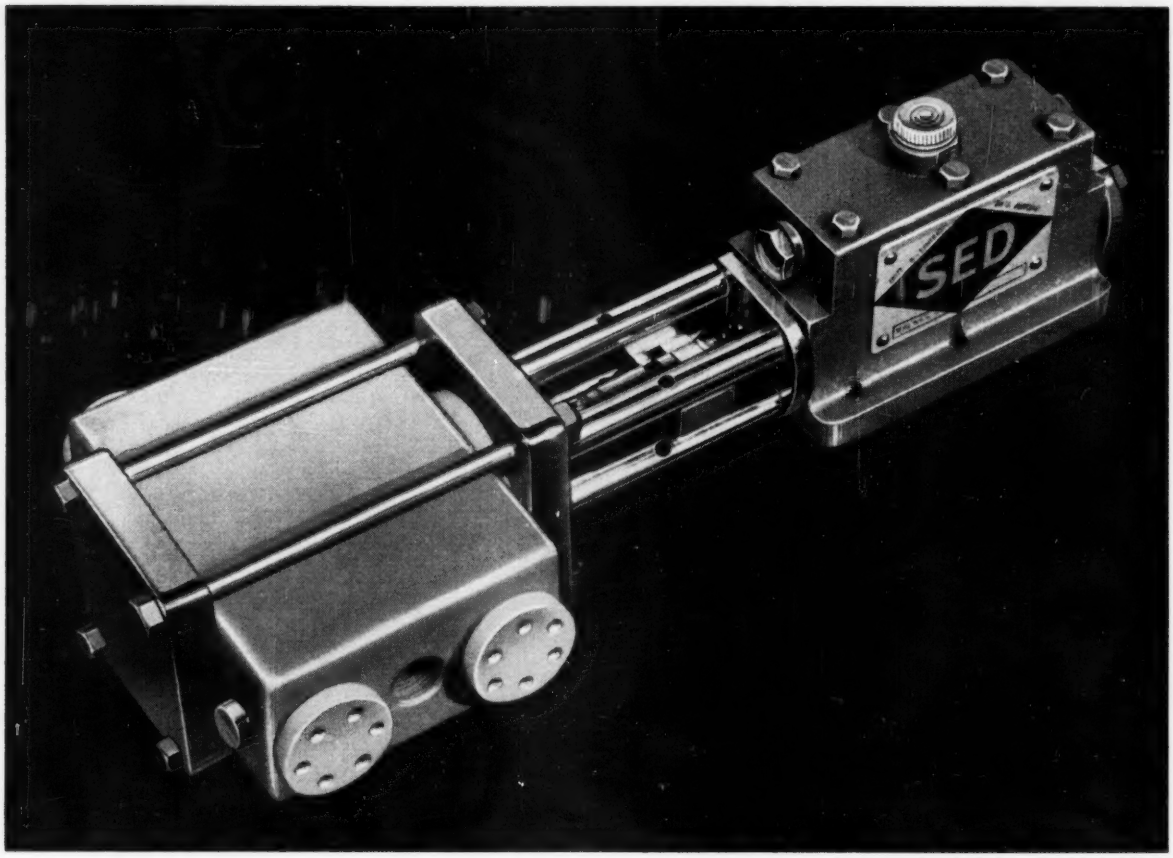
178

ASHMORE, BENSON, PEASE & CO

(MEMBER OF THE POWER-GAS GROUP)

STOCKTON-ON-TEES AND LONDON

AUSTRALIA · CANADA · INDIA · FRANCE · SOUTH AFRICA



Neumo Pump designed and manufactured by S.E.D. Engineering Co. Ltd., and marketed by Kingsbourne Products Ltd., Peacehaven, Sussex.

New corrosion-proof pump made from 'Fluon' polytetrafluoroethylene

A PUMP which is completely inert and gives positive displacement is of outstanding interest to engineers. This is the remarkable achievement of the Neumo 'Fluon' pump.

This pump can operate at pressures up to 40 p.s.i. and is connected in tandem with a piston type air motor which can be stalled without damage.

The liquid being pumped only comes into contact with 'Fluon', the cylinder piston and valves all being made from this fluorocarbon polymer which is only attacked by molten alkali metals and a few fluorine compounds at high temperature and pressure. This not only implies freedom from corrosion but also freedom from contamination.

Advantage is also taken of the very low coefficients of static and dynamic friction of 'Fluon' p.t.f.e. The moving parts require no lubrication and both wear and any tendency to seizing up are reduced to a minimum.

'Fluon' has a working temperature range of at least − 80°C. to + 250°C. and because few materials will stick to it, cleaning becomes a simple operation.

'FLUON'

'Fluon' is the registered trade mark for the polytetrafluoroethylene manufactured by I.C.I.

ICI

IMPERIAL CHEMICAL INDUSTRIES LIMITED · LONDON · S.W.1

PF.35/P

FUNCTIONAL SCALE MODELS

A COMPLETE ENGINEERING SERVICE

With some of the largest and best equipped design offices in Britain the MATTHEW HALL organisation undertakes the complete

- **DESIGN**
- **PROCUREMENT**
- **CONSTRUCTION**
- **COMMISSIONING**

of large oil refinery, chemical and other engineering projects.

THE

MATTHEW HALL

GROUP OF COMPANIES

OIL REFINERY, CHEMICAL & INDUSTRIAL ENGINEERS

EST 1840

MATTHEW HALL

MATTHEW HALL HOUSE, DORSET SQUARE, LONDON, N.W.1.

Manchester · Glasgow · Bristol · Belfast · Johannesburg · Germiston · Durban
Cape Town · Wellpen · Bulawayo · Salisbury (Central Africa) · Ndola · West Indies

Ready-to-use
REFRACTORY CEMENT!

Plastic DURAX '14'

The *Time-Saving Way* to obtain THIN STRONG JOINTS

A ready-to-use jointing mortar supplied in a smooth plastic condition, which may be applied with a trowel in the normal way, or used for "dip and rub" joints.

Durax No. 14 is an aluminous refractory cement which contains a high proportion of pre-calcined material to control shrinkage and produce thin, solid joints which set hard without the application of heat. These joints are as impermeable to the action of the furnaces gases as the bricks themselves, resulting in reduced cool air infiltration and improved thermal efficiency.

Designed for use between 1000°C and 1650°C. For lower temperatures Durax No. 4 is recommended.

★ *Send Today for Descriptive Literature*

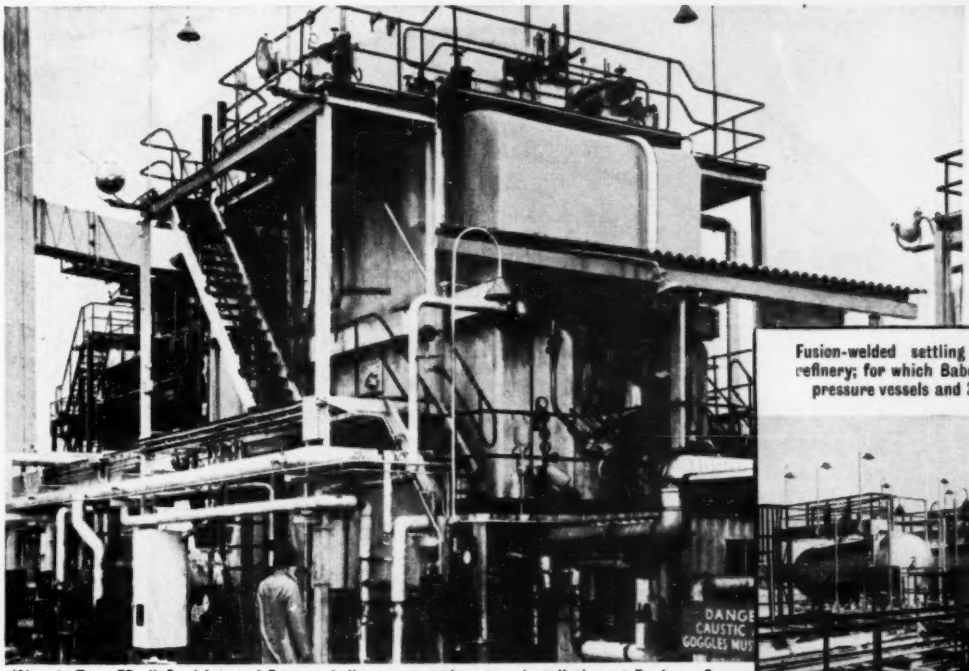
GR

370

Technical advice and assistance on the selection and application of refractories are available on request.

GENERAL REFRACTORIES LTD

GENEFAX HOUSE • SHEFFIELD 10 • Telephone: SHEFFIELD 31113



(Above) Type-FP oil-fired Integral Furnace boiler as an outdoor-type installation, at Fawley refinery.

Fusion-welded settling tanks, at Coryton refinery; for which Babcock supplied over 90 pressure vessels and 30 vertical columns.

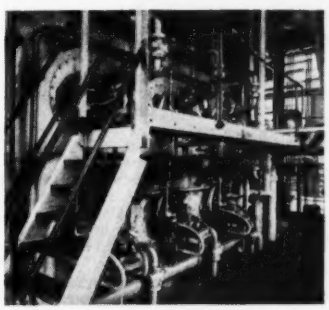
BABCOCK

Equipment for the Oil and Chemical Industries

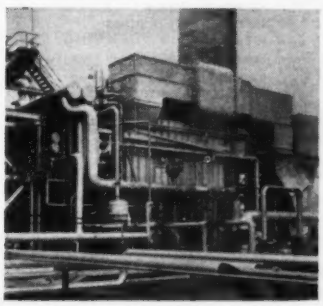
Babcock & Wilcox Ltd. is outstandingly well equipped in experience, techniques and manufacturing facilities to meet the demands of the oil and chemical industries for complete steam-raising plants, pressure vessels (in mild-steel or clad plate), separately-fired superheaters, heat exchangers and waste-heat utilization plant.

Many of the world's largest pressure-vessels have been Babcock fusion-welded, including the giant heat-exchangers of Britain's first atomic power stations and a large number of treating towers for the world's oil refineries and chemical plants. The Company has, indeed, an exceptional experience of fabrication by fusion-welding and, as the world's largest maker of steam-raising plant, has a thorough understanding of the principles and problems of heat-exchange.

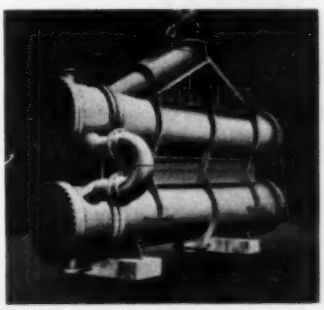
BABCOCK & WILCOX LTD. BABCOCK HOUSE, 209 EUSTON RD. LONDON, N.W.1.



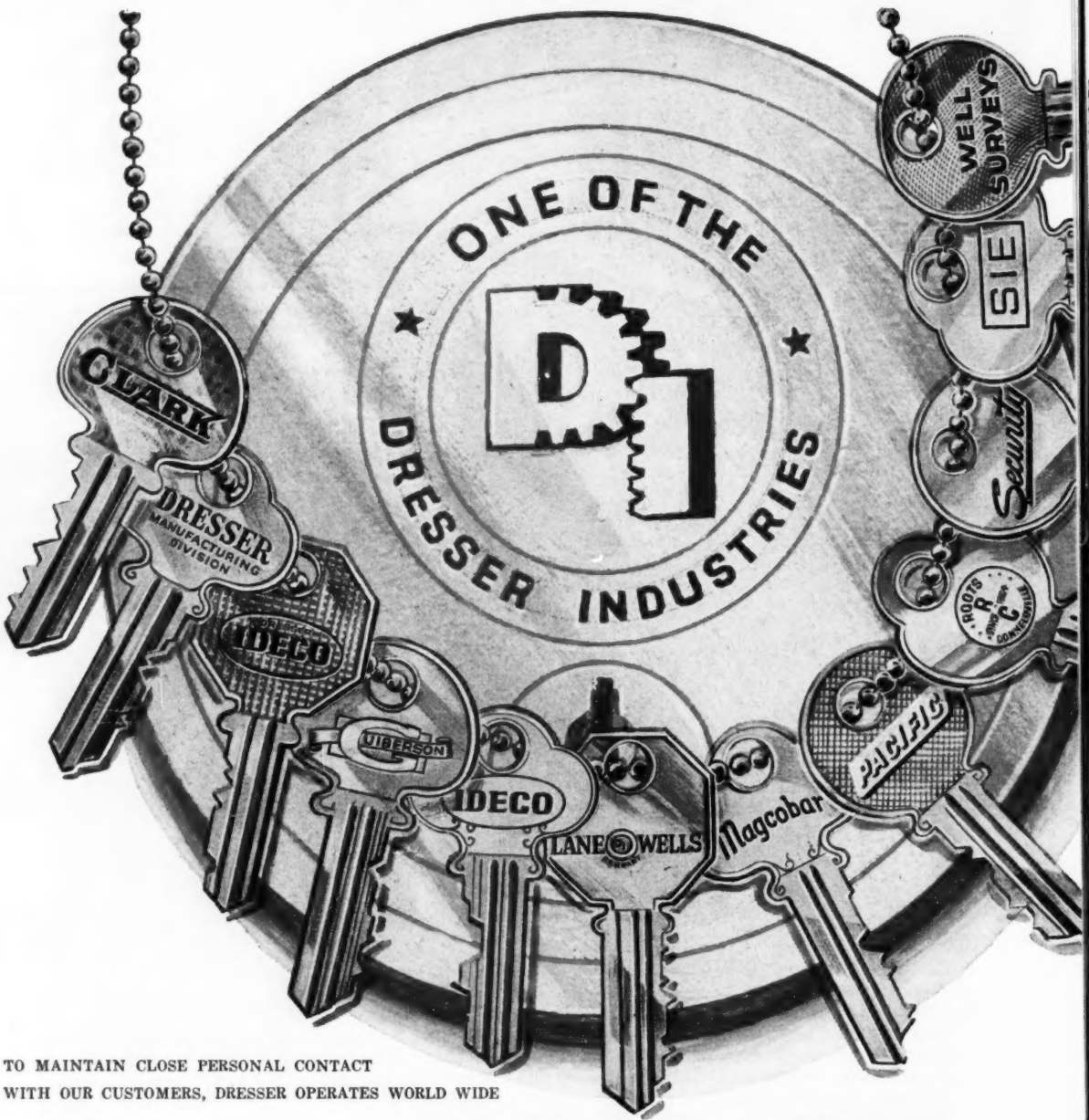
Oil-firing equipment on type FH boiler, Fawley refinery.



Type FH, oil-fired, Integral Furnace boiler as an outdoor installation.



Typical Babcock heat-exchanger for service in an oil-refinery.



TO MAINTAIN CLOSE PERSONAL CONTACT
WITH OUR CUSTOMERS, DRESSER OPERATES WORLD WIDE

CLARK BROS. CO.
Ling House, Dominion Street
London, E.C. 2, England

CLARK COMPRESSOR CO. LTD.
1210 11th Avenue, W.
Calgary, Alberta, Canada

CLARK-ITALY S.p.A.
Via Tembien 41, Rome, Italy

DRESSER A.G.
Mühlebachstrasse 43, Zürich, Switzerland

DRESSER LIMITED, C.A.
Apartado 2728
Caracas, Venezuela

DRESSER INTERNATIONAL, INC.:
Viamonte 867, Buenos Aires, Argentina
Edif. Radio Continente, Ave. México
Los Caobos, Caracas, Venezuela
Clark Bros. Pan American Div.—
Paseo de la Reforma 95-1102;
Southwestern Industrial Electronics Div.—Edison 40-1;
Ideco Div.—813 Edificio Internacional,
Paseo de la Reforma 1, México D. F., México

DRESSER MANUFACTURING COMPANY, LIMITED
1211 Bathurst Street
Toronto 4, Ontario, Canada

DRESSER MANUFACTURES (ENGLAND) LIMITED
39 Victoria Street
London, S.W. 1, England

LANE-WELLS CANADIAN COMPANY
Room 14, 10548 82nd Avenue
Edmonton, Alberta, Canada

MAGNET COVE BARIUM CORPORATION, LTD.
525-A Seventh Avenue, West
Calgary, Alberta, Canada

MAGCOBAR DE MÉXICO, S.A.
Apartado 1742, Monterrey, N.L., México

MAGCOBAR DE VENEZUELA, C.A.
Edif. Luz Eléctrica, Ave. Urdaneta
Caracas, Venezuela

PACIFIC PUMPS OF CANADA, LIMITED
9707 63d Avenue
Edmonton, Alberta, Canada

PETRO-TECH SERVICE, C.A.
Apartado 2728
Caracas, Venezuela

ROOTS-CONNERSVILLE BLOWER (CANADA), LTD.
629 Adelaide St. West
Toronto 3, Ontario, Canada

SECURITY ENGINEERING CANADA LTD.
P.O. Box 4267
Edmonton, Alberta, Canada

SECURITY ROCK BITS LTD.*
Whitworth Street
Openshaw, Manchester 11, England

SOCIÉTÉ FRANCAISE DES INDUSTRIES DRESSER, S.A.
11, rue Auber, Paris, France

SOUTHWESTERN INDUSTRIAL ELECTRONICS (CANADA) LTD.
434 Seventh Ave., East
Calgary, Alberta, Canada

*Majority owned

Keyed to your needs and linked to give DRESSER Plus service

"One of the Dresser Industries" is a well known phrase identifying the family relationship of 12 great Dresser companies which supply equipment and technical services to the oil, gas, chemical, electronic and other industries.

Each Dresser company is independently managed for maximum efficiency. Each possesses global experience, engineering talent and modern manufacturing facilities keyed to the highly technical needs of the industries it serves. Linked by common ownership, Dresser companies can be quickly mobilized to meet special conditions calling for specialized research, engineering or production facilities. This coordinated teamwork is known as Dresser *plus* service. It's an *extra* value provided promptly by men with imagination. The Dresser *plus* is your positive assurance of superior equipment and technical services — the standard of comparison the world over.

Tomorrow's progress planned today

DRESSER INDUSTRIES, INC.

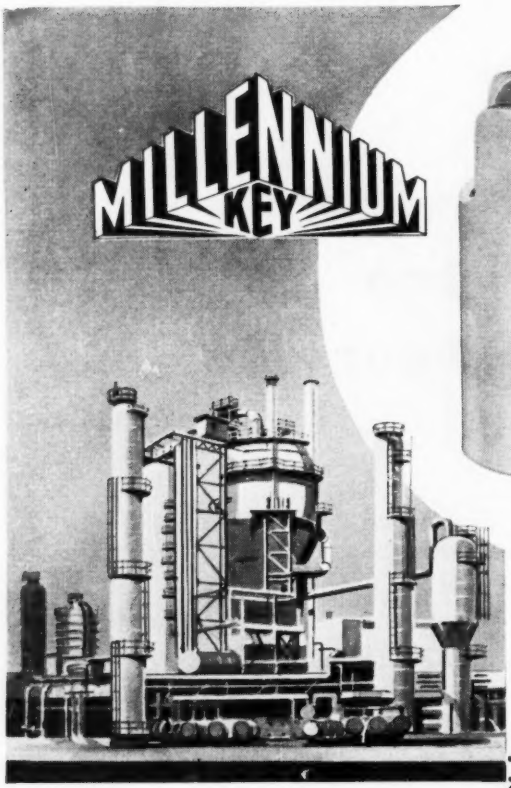
EQUIPMENT AND TECHNICAL SERVICES

OIL • GAS
CHEMICAL
ELECTRONIC
INDUSTRIAL

REPUBLIC NATIONAL BANK BUILDING, DALLAS 21, TEXAS

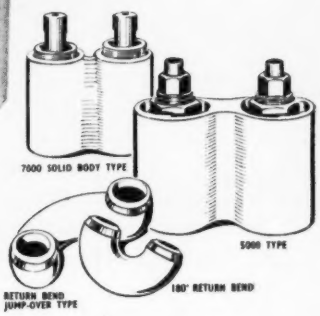
These are the Dresser Industries:

CLARK BROS. CO.—*compressors* • **DRESSER-IDECO COMPANY**—*steel structures* • **DRESSER MANUFACTURING DIVISION**—*couplings* • **THE GUIBERSON CORPORATION**—*oil tools* • **IDECO, INC.**—*drilling rigs* • **LANE-WELLS COMPANY**—*technical oilfield services* • **MAGNET COVE BARIUM CORPORATION**—*drilling mud* • **PACIFIC PUMPS, INC.**—*pumps* • **ROOTS-CONNERSVILLE BLOWER DIVISION**—*blowers* • **SECURITY ENGINEERING DIVISION**—*drilling bits* • **SOUTHWESTERN INDUSTRIAL ELECTRONICS**—*electronic instrumentation* • **WELL SURVEYS, INC.**—*nuclear and electronic research and development.*



1900 OR BOX TYPE

highest quality fittings for refinery and chemical plants



Please write for bulletins which give full technical information on each type of fitting.

Lake & Elliot Ltd.
BRAINTREE · ENGLAND

TEL. BRAINTREE 1491

HANDY VOLUMES OF THE ASTM/IP PETROLEUM MEASUREMENT TABLES

British and Metric Editions

	s.	d.		s.	d.
Vol. A. Interrelation of Units, Gravities and Density and Volumes	2	0	Vol. G. Reduction of Volume 60°F. against Specific Gravity 60/60°F.	5	0
Vol. B. Weights per Unit Volume and Volumes per Unit Weight against Sp. Gr. 60/60°F....	3	6	Vol. H. Miscellaneous Metric Tables ...	3	6
Vol. C. Reduction of Observed Specific Gravity and Volume to 60°F. For LPG and Casinghead Gasoline	5	0	Vol. I. Reduction of Observed Density and Volume to 15°C. For LPG and Casinghead Gasoline	6	0
Vol. D. For Aviation Gasoline, Motor Gasoline, Kerosine and Gas Oil	6	0	Vol. J. For Aviation Gasoline, Motor Gasoline, Kerosine and Gas Oil	6	6
Vol. E. For Diesel Fuel and Fuel Oils ...	6	6	Vol. K. For Diesel Fuel and Fuel Oils ...	7	6
Vol. F. For Fuel Oils and Bitumen	6	6	Vol. L. For Fuel Oils and Bitumen	7	6

British Tables A—G; Metric Tables H—L

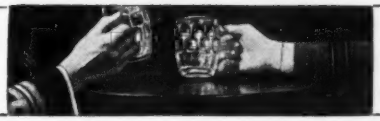
Obtainable from:—

INSTITUTE OF PETROLEUM
61 New Cavendish Street, London, W.1

I'm fed up with filters!
let's sit down...

Let's sit down and talk about cricket, the weather... anything so long as it isn't your confounded Simmonds Fram Separators.

Sorry old man . . . didn't mean to bore you.



That's quite all right. Delighted to know the R.A.F. is getting up to date. So you actually fly your planes on kerosene now instead of water!

Very comical! Anyway, it's not the whole point. I admit the main object of Simmonds Fram Separators is to remove all the water, but they also take out the solids.

Little strips of erk, for instance?

. . . Anything down to 5 microns.

That gives me a big kick.
Which is more than I can say for this brew . . .

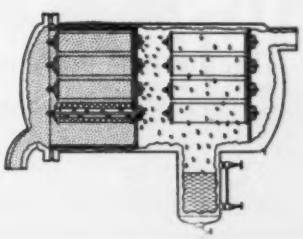
There you are. Now if we could persuade Sally to fit Simmonds Water Separators to the barrels . . .

the point of the argument... **FRAM SEPARATOR FILTERS**
for clean water-free fuel

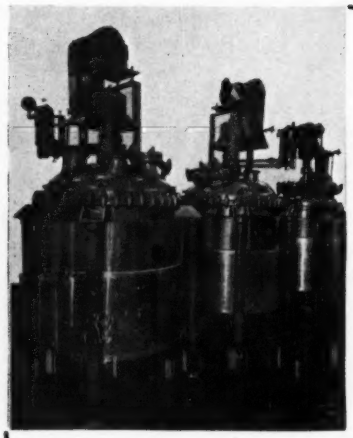
For more details of this and other Simmonds products for the aviation industry **SEND FOR LITERATURE** *to*

SIMMONDS AEROCESSORIES LTD.
Byron House, 7-8-9, St James's Street, London, S.W.1.
Head Office & Works: Treforest, Pontypridd, Glamorgan.
Also Birmingham, Manchester, Glasgow, Stockholm, Copenhagen, Ballarat, Sydney, Johannesburg, Amsterdam and New York.

A MEMBER OF THE FIRTH CLEVELAND GROUP FC



CRC 5W3



STABILAG HEATING MANTLES

For accurate controls in distillation and fractionation operations, for high temperature work, and in concerns where steam or other heating medium are not available, Stabilag Electric Heating Mantles are the complete answer.
Installation costs with Stabilag Mantles are negligible; also they have the great advantage of multi-zone heating which is arranged by tiers of circular elements operating independently and thereby giving heat exactly where it is required. Construction of these, as of all Stabilag products, is of the very highest quality. Send for literature and full details to:—

THE STABILAG CO. LTD. (Dept. C4),
Mark Road, Hemel Hempstead, Herts. BOXmoor 4481

STANDARD METHODS
FOR
TESTING PETROLEUM
AND
ITS PRODUCTS

(Excluding Engine Test Methods for Rating Fuels)

(SEVENTEENTH EDITION, 1958)

788 pages Illustrated

Price 40s. post free

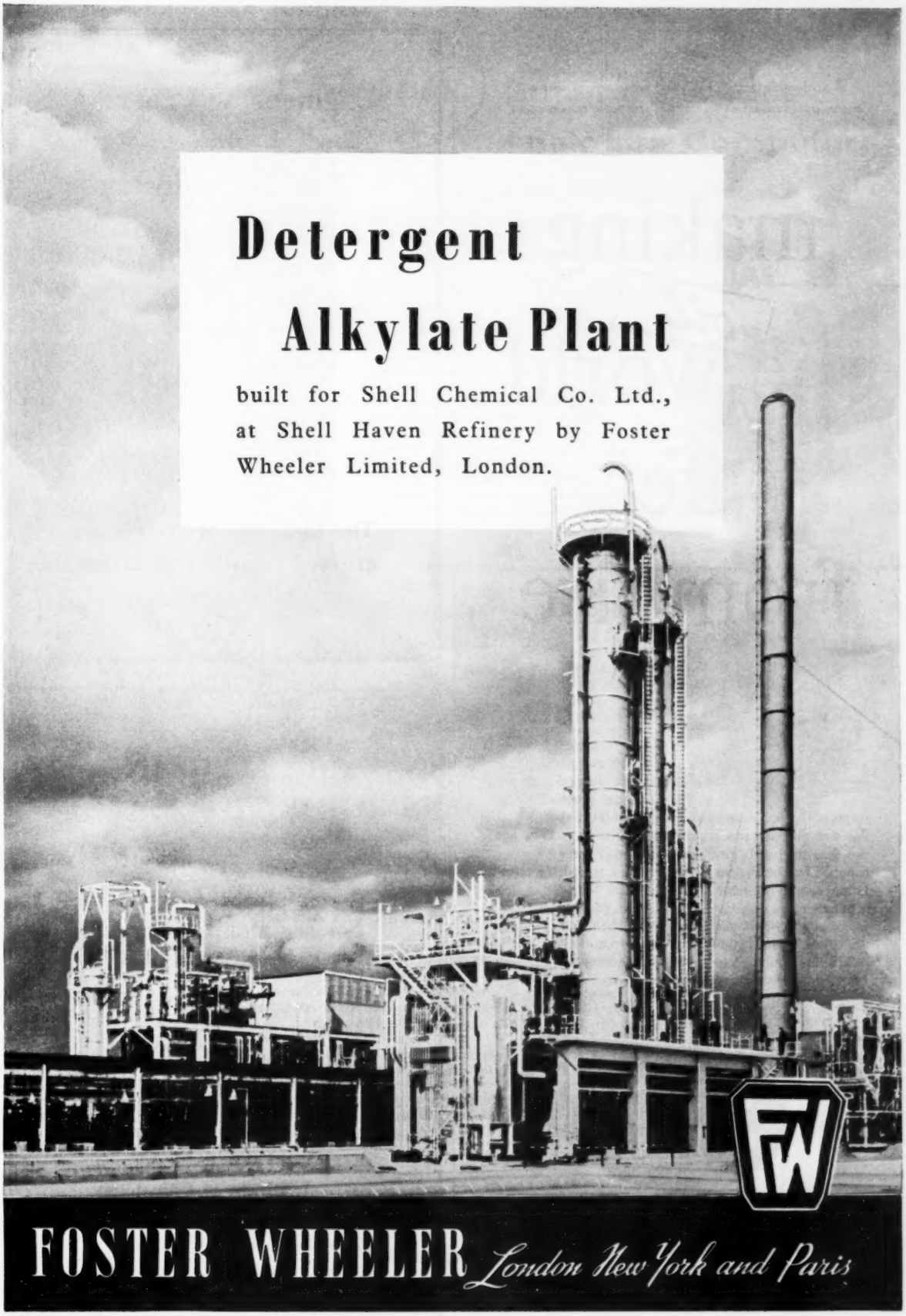
Obtainable from

The Institute of Petroleum
61 New Cavendish Street,
London, W.1

ADVERTISERS

(Advertising Agencies in Italics)

Babcock & Wilcox Ltd xi
(S. H. Wright & Co. Ltd)
Baker Oil Tools Inc. iii
(Martin-Ripley, Advertising)
Birmingham Battery & Metal Co. Ltd . . July
(Maurice G. Parker Ltd)
Peter Brotherhood Ltd . . . . . Mar.
(J. Peers & Associates Ltd)
W. P. Butterfield Ltd . . . . . Mar.
(Storey, Evans & Co. Ltd)
Cape Asbestos Co. Ltd, The, ... Mar.
(Taylor Advertising Ltd)
Contoura Photocopying . . . . Jan.
(Richmond Towers Ltd)
A. F. Craig & Co. Ltd iv
(Taylor Advertising Ltd)
Dorr-Oliver Co. Ltd . . . . . Mar.
Dresser Industries Inc. . . . . xii & xiii
(The McCarty Co. Advertising Inc.)
Electroflo Meters Co. Ltd . . . . Mar.
(C. P. Wakefield Ltd)
Foster Wheeler Ltd xvii
(Wm Hopwood & Co. Ltd)
Foxboro-Yoxall Ltd . . . . . Mar.
W. J. Fraser & Co. Ltd . . . . . Mar.
(Technical Advertising Service)
General Refractories Ltd x
(John Mitchell & Partners Ltd)
Matthew Hall & Co. Ltd ix
Hughes Tool Company . . . . . Mar.
(Foote, Cone & Belding Ltd)
Imperial Chemical Industries Ltd (Plastics Div'n) viii
(S. H. Benson Ltd)
Kellogg International Corporation . . . vi
(Reynell & Son Ltd)
Richard Klinger Ltd i
(R. F. White & Son Ltd)
Lake & Elliot Ltd xiv
(Ripley, Preston & Co. Ltd)
A. & J. Main & Co. Ltd . . . . . Mar.
(Hannaford & Goodman Ltd)
Marston Excelsior Ltd v
(Clifford Martin Ltd)
Metropolitan-Vickers Electrical Co. Ltd . . Mar.
(Technical & General Advertising Agency Ltd)
A. P. Newall & Co. Ltd . . . . . Mar.
(Osborne-Peacock Co. Ltd)
Newman, Hender & Co. Ltd . . . . Mar.
(Adams Bros & Shardlow Ltd)
Power-Gas Corporation, The, ... vii
Procon (Great Britain) Ltd xx
(Sam. J. Gallay Advertising)
Pyrene Co. Ltd xviii
(Nelson Advertising Service Ltd)
Short Bros. & Harland Ltd xix
(S. T. Garland Advertising Services Ltd)
Simmonds Aerocessories Ltd xv
(C. R. Casson Ltd)
Societe Nationale de Materiel pour la Recherche et l'Exploitation du Petrole . . . xvi
Stabilag Co. Ltd, The, ... xvi
(Bastable Publicity Ltd)
Townson & Mercer Ltd . . . . . Mar.
Universal Oil Products Co. . . . . Mar.
(Sam J. Gallay Advertising)
Wailes Dove Bitumastic Ltd ii
Henry Wiggin & Co. Ltd . Inside back cover
(Technical & General Advertising Agency Ltd)
Yorkshire Imperial Metals Ltd . . . . Mar.


Detergent
Alkylate Plant
built for Shell Chemical Co. Ltd.,
at Shell Haven Refinery by Foster
Wheeler Limited, London.
FW
FOSTER WHEELER London New York and Paris

BY APPOINTMENT TO HER MAJESTY THE QUEEN
Suppliers of Fire Extinguishers *The Pyrene Company Limited*

making oil the world safer from fire

The many and varied fire dangers that are ever present in all stages of the processing and storage of oil call for nothing less than the finest modern methods of fire protection. In this field the highly developed and specialized equipment supplied by The Pyrene Company has a record and reputation second to none throughout the world. In the production of aviation and motor spirit, kerosene, fuel and lubricating oils, bitumen, petroleum chemicals, alcohols and solvents—and in their increasingly wide uses in industry—there are no fire problems beyond the scope of "Pyrene" Fire Protection. *For full details of important "Pyrene" development please write to Dept. J.I.P.4.*

Pyrene TRADE MARK FIRE PROTECTION

THE PYRENE COMPANY LIMITED

9 GROSVENOR GARDENS LONDON SW1 *Tel:* VICtoria 3401
Head Office & Works: GREAT WEST ROAD . BRENTFORD . MIDDX
Canadian Plant: TORONTO

Engineering Progress and The Oil Industry

This book contains the seven papers presented at the 1957 Summer Meeting of the Institute. It covers every phase of the oil industry, from exploration to distribution, and contains also much useful information of a general character.

168 pages Illustrated

Price **30s 0d** post free

Obtainable from

The Institute of Petroleum
61 New Cavendish Street
London, W.1

DRILLING AND PRODUCTION SAFETY CODE

(Loose Leaf)

Part 4 of Model Code of Safe Practice in the Petroleum Industry

Price 12s. 6d. post free

A 3-ring binder to hold this and three other codes can be supplied at the price of 15s. 6d.

Obtainable from

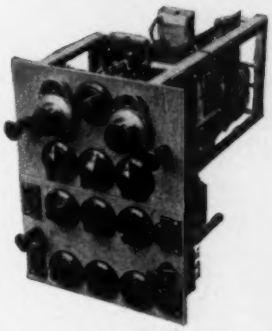
The Institute of Petroleum
61 New Cavendish Street,
London, W.1

Shorts **General Purpose Analogue Computor**

The extended range of non-linear computing units now available increases the versatility of the compact Short Computor. Write for Data Sheets on these units.

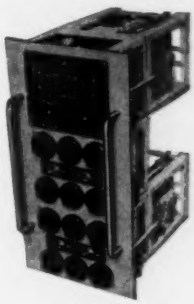
variable time switch unit

This unit permits the solution of problems in which the coefficients are changed from one discrete value to another, either after a given time or when a variable reaches a pre-determined value during the period of computation.
The unit will therefore find application to problems in which a simulation is required of transient performance under abruptly changing conditions, or to problems involving integration between two limits.



servo multiplier unit

This unit supplements the HIGH SPEED MULTIPLIER UNIT. It permits four separate variables to be multiplied by one common variable.

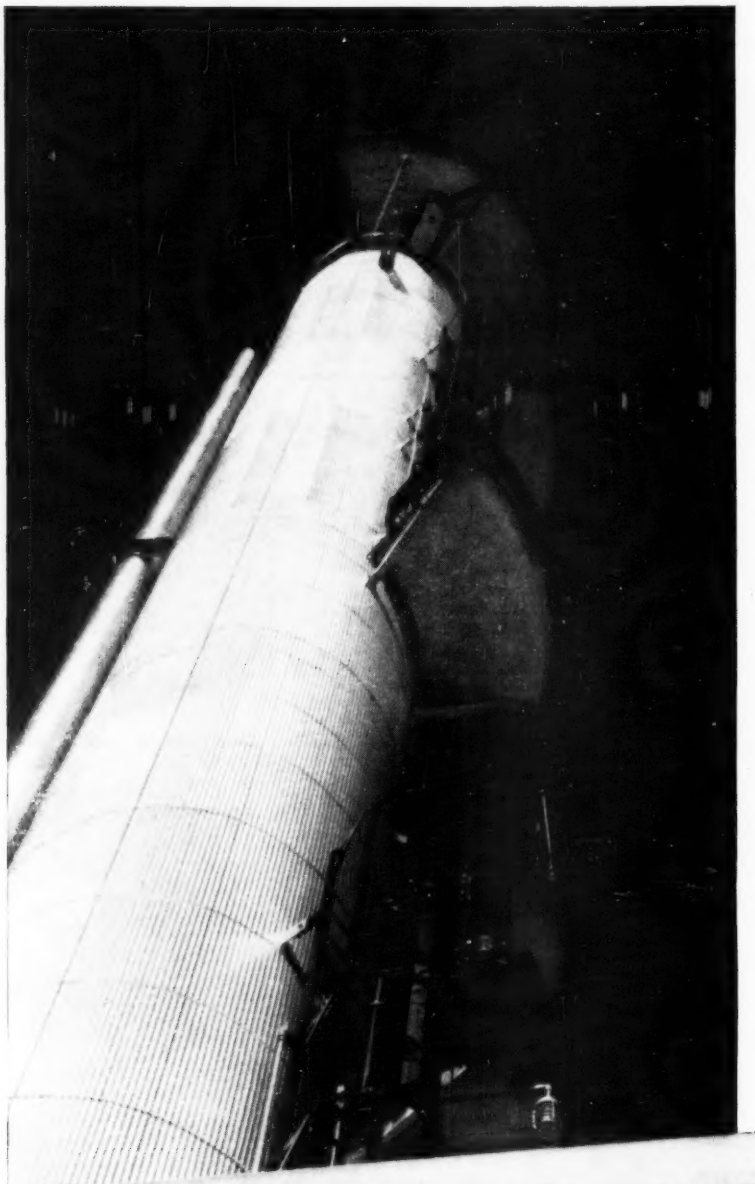


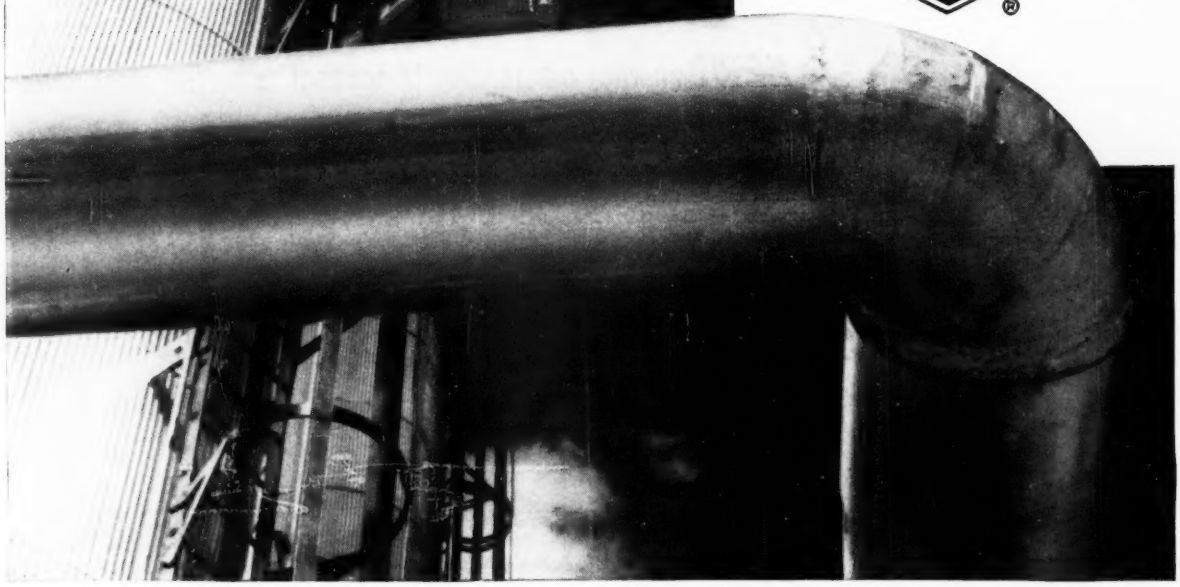
NEW! another outstanding instrument from the same team

the low-frequency decade oscillator

This oscillator has been designed for testing servo-mechanisms and electrical systems where inputs of extremely low distortion and accurate amplitude are essential. It employs three drift-corrected computing-type amplifiers to generate a sinusoidal oscillation in the range 0.01 to 110 c/s, according to the setting of the 3-decade frequency control. "Step" and "Ramp" functions may also be generated, and the total distortion is less than 0.5%.

All enquiries to: Short Brothers & Harland Ltd., Computor Sales Department, 208a Regent Street, W.1. REGent 8716





there's more to good construction than meets the eye

A fine construction job has a lot of eye appeal. At Procon we're pretty proud of the way our finished projects look. The most satisfaction, though, is in knowing that behind the trim, functional beauty we've put the soundness of design, the careful planning, the quality of construction to fulfill the most exacting operational requirements.

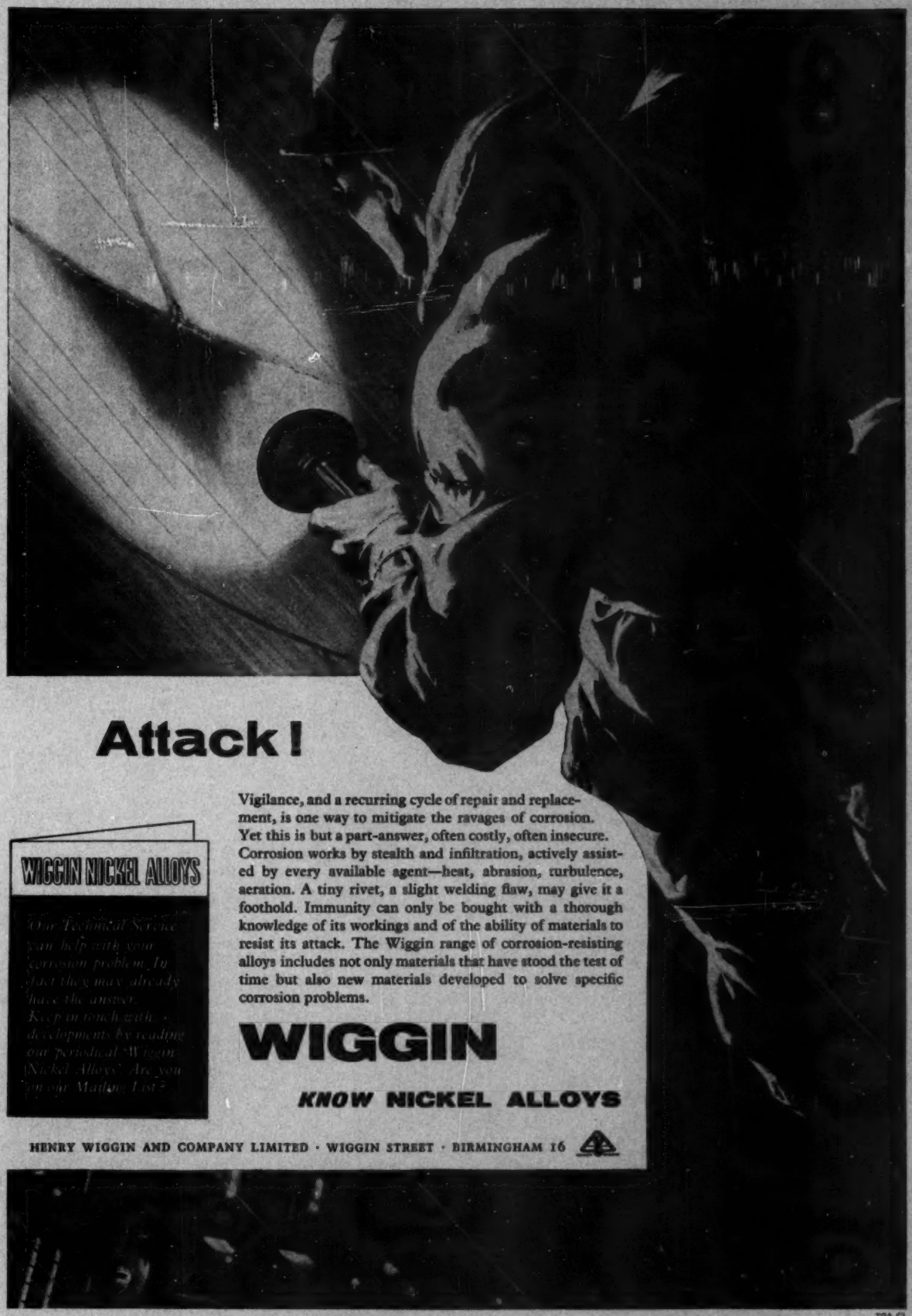
If you want your building project to function just as well as it looks, why not let Procon show you how it's done. We've been building well for the petroleum refining, petrochemical and chemical industries for years.

PROCON (*Great Britain*) LIMITED
BUSH HOUSE, ALDWYCH, LONDON, W. C. 2, ENGLAND

PROCON INCORPORATED, DES PLAINES, ILLINOIS, U. S. A.
PROCON (CANADA) LIMITED, TORONTO 18, ONTARIO, CANADA
PROCON INTERNATIONAL S. A., SANTIAGO DE CUBA

WORLD-WIDE CONSTRUCTION FOR THE PETROLEUM, PETROCHEMICAL, AND CHEMICAL INDUSTRIES

PROCON®



Attack!

Vigilance, and a recurring cycle of repair and replacement, is one way to mitigate the ravages of corrosion. Yet this is but a part-answer, often costly, often insecure. Corrosion works by stealth and infiltration, actively assisted by every available agent—heat, abrasion, turbulence, aeration. A tiny rivet, a slight welding flaw, may give it a foothold. Immunity can only be bought with a thorough knowledge of its workings and of the ability of materials to resist its attack. The Wiggin range of corrosion-resisting alloys includes not only materials that have stood the test of time but also new materials developed to solve specific corrosion problems.

WIGGIN NICKEL ALLOYS

Our Technical Service can help with your corrosion problem. In fact they may already have the answer. Keep in touch with developments by reading our periodical 'Wiggin Nickel Alloys'. Are you on our Mailing List?

WIGGIN

***KNOW* NICKEL ALLOYS**

HENRY WIGGIN AND COMPANY LIMITED · WIGGIN STREET · BIRMINGHAM 16

TGA C1